

**SURVEY OF TRANSITING EXTRASOLAR
PLANETS AT THE UNIVERSITY OF
PITTSBURGH**

by

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In the past two decades, a wealth of planets and planetary candidates orbiting other stars have been discovered and are awaiting more follow-up study to further characterize them. To pursue such follow-up avenues, I recruited a research team of undergraduate collaborators for a project we named Survey of Transiting Extrasolar Planets at the University of Pittsburgh (STEPUP). Since its inception in August 2009, STEPUP has investigated both known planets and planetary candidates, making use of the Allegheny Observatory's 16" Meade LX-400 ACF telescope. In total we have taken 90 nights' worth of data, observing 17 stars hosting known or suspected substellar companions. We have been able to confirm transits of known gas giant planets such as XO-2b, TrES-2b, and HD80606b. In fact, our observations of HD80606b contributed to an international ground-based effort to collaboratively observe this long transit, a collaboration which demonstrated the success of coordinating observations across geographical distances. Our transit detections indicate our ability to obtain relative photometric precision of roughly 1%. In addition to studying known transiting planets, STEPUP has worked with the SDSS-III MARVELS team to search for transits of planetary candidates, which, if detected could help confirm the planetary nature of those candidates.

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1.0 INTRODUCTION

1.1 OVERVIEW

Are we alone in the universe? This is an age-old question which until recently was traditionally part of the realm of philosophy. As far as we know, the answer to this question relies on whether or not other planets that could support life exist. The origin of the word “planets,” in fact, is a misnomer, since it comes from the Greek term for “wandering stars” ([Carroll and Ostlie, 2007](#), p. 2). It wasn’t until after the Copernican revolution that we began to understand that planets were not stars at all but actually other worlds which orbited stars. With this paradigm shift came fanciful speculations of life on other planets, such as those presented in Christiaan Huygens’ *New Conjectures Concerning the Planetary Worlds, Their Inhabitants and Productions*, c. 1690. The dreamy visions of extraterrestrial life in our own solar system, of course, met their end when the other planets in our solar system were more closely examined in the 20th Century and shown to be largely inhospitable to life. Yet by the time probes had ruled out the likelihood of life on other planets in the solar system, we knew our star was one of only billions in our galaxy. So the fact that life existed on at least one of the planets of our own solar system naturally led to the question of whether or not there could be habitable worlds orbiting other stars.

For most of the 20th Century, planetary formation theories and models seemed to suggest that if planets orbited other stars, though they would likely be somewhat different from the planets of our solar system, their distances from their star would roughly mimic our solar system, with larger planets orbiting farther out and smaller planets orbiting closer in

([Isaacman and Sagan, 1977](#); [Boss, 1993, 1995](#)). Similarly, in the majority of cases, their orbital eccentricities would likely be nearly circular ([Isaacman and Sagan, 1977](#)), and we could describe relationships between their mass and radius using arguments of composition and density that were thought to be understood based on our solar system ([Hartmann, 2005](#); [Lunine et al., 2008](#)).

Yet, when the first extrasolar planets were found near the turn of this Century, these conventional expectations were challenged. For a detailed account of the history of early extrasolar planet discoveries and the ways in which such discoveries challenged scientific notions at the time, see Chapter 3 of the *Report of the Exoplanet Task Force to the Astronomy and Astrophysics Advisory Committee* ([Lunine et al., 2008](#)). Or for a more concise overview, see Section 7.1 in the *Exoplanet Community Report* ([Lawson and Unwin, 2009](#)). Here I summarize the details of such accounts:

The astounding announcement in 1995 of the discovery of 51 Pegasi b by [Mayor and Queloz](#) was just the first of many Jupiter-sized planets were found not at several AU away from their star, but at fractions of an AU from their star, roasting in an environment we never would have predicted. Many of these “hot Jupiters,” as they came to be known, were found to have unexpectedly large radii, and some extrasolar planets were also found to be on highly eccentric orbits. Astronomers quickly learned that nature exhibits great diversity when it comes to planets, and that it is not safe to take much for granted about what we should expect to find.

If there is one lesson we should take away from our tendency towards a human-centric view of the universe, it is that science is about understanding nature as it is, not as we wish it to be. Still, the motivation behind these age-old questions of our place in the universe is a driving force behind our quest.

1.2 CONTEMPORARY UNDERSTANDING OF EXTRASOLAR PLANETS

At the present time, planets ranging in size from several times Jupiter’s mass down to a couple times Earth’s mass have been found. Many are on close-in orbits, but some orbit far from their star. A few gas giants are near that most precious place, the “habitable zone.” At least one rocky planet may just barely be within that zone, though the exact number of planets in this system (Gliese 581) and their potential habitability are still being disputed (Vogt et al., 2010; Tuomi, 2011; von Paris et al., 2011; Wordsworth et al., 2010; von Paris et al., 2010; Wordsworth et al., 2011). But so far, no true Earth-analogs have been definitively discovered and confirmed. This is likely to change in the near future since the launch of the Kepler Mission in March 2009. This NASA mission put a 1.4m telescope into an earth-trailing heliocentric orbit. From this orbit, Kepler will constantly monitor a region of the sky in the constellations of Cygnus and Lyra for the next 3.5 to 6 years searching for earth-sized planets in the habitable zones of stars in this region of the sky¹. However, even when Kepler finds a candidate Earth analog, it will likely orbit a star far away in Kepler’s limited fixed field of view, and follow-up observing from the ground could be challenging. In the meantime, ground-based astronomers have the rest of the sky to explore, and a multitude of worlds to characterize.

Most of the known planets outside our solar system were discovered by a technique that exploits the Doppler shift². This technique is usually referred to as the radial velocity technique, and it involves measuring tiny periodic shifts in the spectra of stars that might indicate a planet gravitationally tugging on the star (Carroll and Ostlie, 2007, pp. 180-198). The advantage of this technique is that, in principle, at some points in the planet’s orbit, there should be a component of light that is Doppler-shifted in any planetary system that is not oriented completely face-on to our line of sight (ie. the angle of inclination, conventionally termed i , is zero in a face-on system). In practice however, the technique is most sensitive when that component is large, which means larger angles and/or more

¹<http://kepler.nasa.gov/Mission/QuickGuide/faq/>

²<http://exoplanet.eu>

massive planets and/or planets orbiting close to their stars (since gravitational force decreases with increasing distance and so weakens the signal in the spectrum). Also once a planet is discovered, only a lower-limit of its mass can be made with this technique since, assuming the mass of the host star is known, only $M_p \sin i$ can be determined (where M_p is the mass of the planet). Thus there is a degeneracy of solutions with different possible angles corresponding to different exact masses (Mason, 2008).

In addition to the radial velocity technique, there are several other techniques that can be used to detect extrasolar planets, such as direct imaging, astrometry, microlensing, and photometric transit technique. Each technique has advantages and disadvantages, but the most fruitful method by far has been the radial velocity technique, followed by the transit techniques (Mason, 2008).

1.3 MOTIVATION FOR THE CURRENT STUDY

The University of Pittsburgh is fortunate to have the Allegheny Observatory at its disposal for astronomical research. Throughout its long history, much in the way of observational research has taken place here, such as the study of the rings of Saturn, the measurement of the distances to and proper motion of nearby stars via their parallax angles, the obtaining of lightcurves of Cepheid variables and eclipsing binaries, and searches for extrasolar planets (originally using the astrometric method—see Section 2.1)³.

Currently at the Allegheny Observatory we do not have the capability to use the radial velocity technique to study extrasolar planets; however, we do have the ability to use the transit technique. The transit technique is responsible for the discovery of over a hundred planets to date, and relies on a planetary system being aligned edge-on to our line of sight (ie. the inclination angle, i , is approximately 90°). In such a system, a planet will, from our perspective, cross directly between us and the parent star at some point in its orbit. In so

³<http://www.pitt.edu/~aobsvtry/history.html>

doing, it blocks out a tiny but detectable fraction of light we receive from the star.

Like the radial velocity technique, the transit technique is most sensitive to large planets. This is due to the fact that more starlight is blocked out for such systems since this stellar dimming is directly proportional to the circular area we see; ie. it is proportional to the square of the planet-to-stellar radius ratio: R_p^2/R_*^2 (see Section 2.3.2). Clearly, then, the smaller the star, the smaller the planet can be in order to be easily detectable. In other words, a terrestrial-sized planet blocks out a much smaller portion of the light of a G star like our sun, for example, than would the same planet orbiting a much smaller M star, and so it would be easier to detect an earth-sized planet if it orbits an M star compared to the same planet orbiting a G star. But for any planet detected via the transit technique, there is a multitude of information we can learn about that planet.

By measuring the light of the parent star and quantifying how much it is dimmed as a function of time, we can plot a “lightcurve” of the star, which is characterized by bright measurements followed by an “ingress,” which is characterized by dimmer measurements and then an “egress” which is characterized by brighter measurements as the planet completes its transit. Examining the change in flux, or the “transit depth,” tells us about the ratio of the planet to stellar radius (see Figure 1.1). Also if we have radial velocity mass estimates, we can break the degeneracy of $M_p \sin i$ by taking $\sin i = 1$, since i must be very close to 90° for a transit to occur. Using this mass and the planet to stellar radius ratio, we can determine the density of the planet if the stellar radius is known. In addition, we can determine the orbital speed and period from the duration of the transit and the amount of time between transits. This makes transit follow-up observations useful in characterizing known planets, if we are fortunate enough to find that these planets do indeed transit.

Another use of transit follow-up observations is in helping to understand the nature of a planetary candidate. If we happen to find a transit occur for a system which has previously exhibited a tantalizing periodic radial velocity signal, we can confirm that the signal is genuine and determine the size of the planet. We are unable to rule out the existence of a substellar companion if we do not find a transit, since the system could be aligned too far

from $i = 90^\circ$ for a transit to occur; however, nature has nonetheless generously bestowed us with certain planetary systems that happen to be aligned in a most precious edge-on way. Indeed the geometric probability of a planet transiting its star is, in general, a non-negligible one, typically ranging between 1 and 10 % (Mazeh, 2009). For a star of a given radius, R_* , with an orbiting planet of radius R_p and semi-major axis, a , the probability of transit is:

$$Prob(transit) \approx \frac{2(R_* + R_p)}{\pi a} \quad (1.1)$$

This can be seen geometrically in Figure 1.2. Equation 1.1 implies that planets orbiting close to their stars will have an enhanced probability of transiting compared to the same planet orbiting far from its star. This probability enhancement combined with the larger transit depth for a larger planet is why planetary transit discoveries, like radial velocity discoveries, tend to be of the “hot Jupiter” variety.

So we can determine the odds that a planetary candidate will transit, and if we are able to find such a transit, we learn important information about the system under study. Thus transit detection is only one piece of the puzzle of learning about extrasolar planets, but it is a very important piece of the puzzle.

1.4 BEGINNINGS OF CURRENT STUDY

My interest in extrasolar planets began while I was still an undergraduate, and I was fortunate to have the opportunity to start research in this field thanks to the Emil Sanielevici Undergraduate Research Scholarship of which I was co-recipient in 2008. At that point I wanted to follow up on observing known transiting planets since this would be the easiest starting point to prove that it was possible to detect transits using the 16” Meade LX-400ACF ⁴ at the Allegheny Observatory. As presented in my talk in February 2009, as an

⁴This particular model of Meade was formerly known as the Meade RCX-400, but was re-named the Meade LX-400ACF to reflect that it is not truly a Ritchey-Chretien design: <http://www.meade.com/lx400-acf/index.html>

undergraduate, I successfully detected the ingress of a transit of XO-2b (a known transiting planet) using very rudimentary analysis methods. (Good, 2009) These methods involved using Mira, a GUI software installed on the computers at the Allegheny Observatory, to measure the photometry of XO-2 and two reference stars by hand in each individual image of my data set. Then I took those measurements and, using Mathcad, manually created arrays, calculated the relative magnitudes, and plotted the results (see Figure 1.3). (Good, 2009) While this approach was successful it was very tedious and so when I began my graduate research, my first goal was to make the analysis more automated.

Thus I spent the summer of 2009 learning Interactive Data Language (IDL) and developing code to re-analyze the XO-2b transit data I had gathered as an undergraduate. I was successful both in developing an automated way to measure photometry of a set of data and in confirming the ingress of the transit I had detected using my less-sophisticated analysis method. Furthermore, the automated method using IDL yielded less error since it was not prone to the lack of accuracy of “pointing and clicking” on the star when performing photometric measurements. Instead, I used a star catalog to astrometrically align my images and specified the center of the aperture photometry for each star by inputting their RA and Dec. The results of this first IDL analysis can be seen in Figure 1.4.

By the beginning of the fall of 2009, I was working on generalizing the code I had developed in order to allow it to take any star field as input and then output a lightcurve of the relative photometric measurements. Two additional functions I included were: 1. proper calibration of the images using a flat, dark, and bias images, and 2. tracking the Julian Date of each image and using Julian Date on the x-axis of my plots instead of the image number to more accurately plot brightness vs. time.

The fall of 2009 also saw the birth of my research team project: Survey of Transiting Extrasolar Planets at University of Pittsburgh (STEPUP). With the support of and under the direction of Prof. Michael Wood-Vasey, several undergraduates were recruited to help in my extrasolar planet research efforts. The original mission statement of STEPUP was to create a group project to focus initially on observing known transiting systems and, as the

project grew, to embark upon more ambitious follow-up and discovery research. The five year science objectives were to:

1. Obtain lightcurves of known transiting extrasolar planets using the 16" Meade LX-400ACF and 30" Thaw telescope and search for any anomalies in transit timing.
2. Survey known extrasolar planets not yet known to transit for evidence of transits.
3. Survey additional stars, especially including M stars, for new discoveries using the 30" Thaw telescope and the 16" Meade LX-400ACF.
4. Follow up, as needed, on targets of particular interest, and participate, if possible, in the discovery confirmation process.
5. Educate and train undergraduate students to enhance their observation skills, increase their awareness of current scientific research, and help prepare them to contribute to extrasolar planet or other astronomic research.

I am happy to report that in the first two years, STEPUP has made great strides in most of these science objectives and has begun work on all of them. The main challenges we face are in helping undergraduates find the balance between their research responsibilities and their coursework responsibilities, making ongoing technical improvements at the Allegheny Observatory, understanding our sources of error, and dealing with suboptimal weather and seeing conditions. Despite these challenges, STEPUP has been able to help make hardware improvements, further develop our software and analysis procedure, observe some important science targets and contribute data to two different scientific collaborations. Furthermore, the stage has been set for STEPUP to continue making contributions to the greater scientific community. For a listing of past and present STEPUP members, see table [1.1](#).

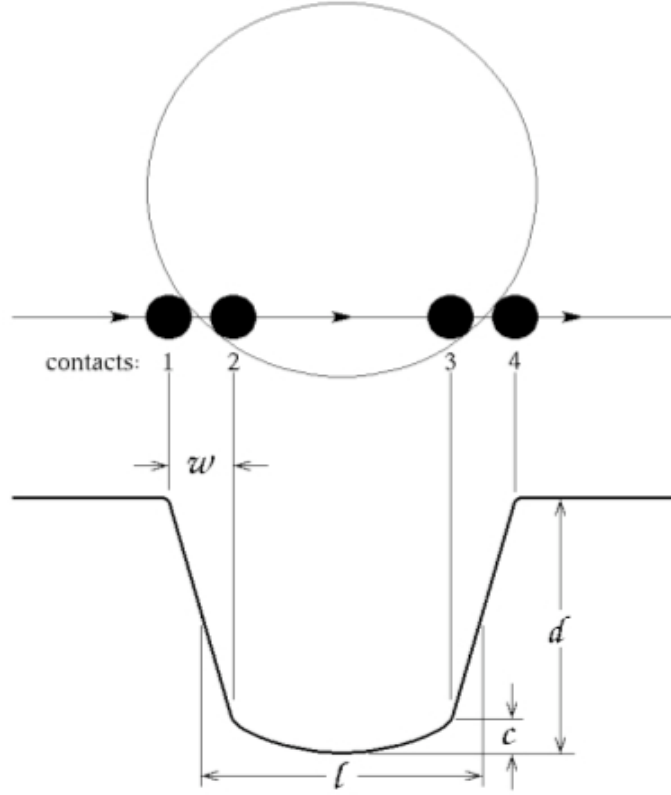


Figure 1.1: [Brown et al. \(2001\)](#) lightcurve Schematic: l is the transit length, w is the duration of the ingress/egress, d is the transit depth, and c is the central curvature of the lightcurve, which can tell us about the degree of limb darkening

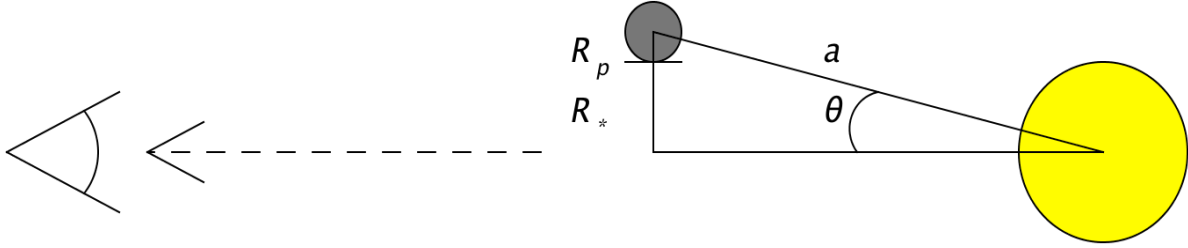


Figure 1.2: Depicted here is the geometry of a grazing planetary transit. This particular θ (which is equal to $\frac{\pi}{2} - i$) corresponds to the minimum angle needed for a transit to take place. From this diagram we can see that $\sin \theta = \frac{R_* + R_p}{a}$. For a small angle $\sin \theta \approx \theta$. To determine the probability that a planet will transit, then, we need only look at the proportion of transiting angles out of all possible angles. That range of angles is 2θ out of π . Thus the probability of a planetary transit is $\frac{2\theta}{\pi} \approx \frac{2(R_* + R_p)}{\pi a}$ which agrees with Equation 1.1.

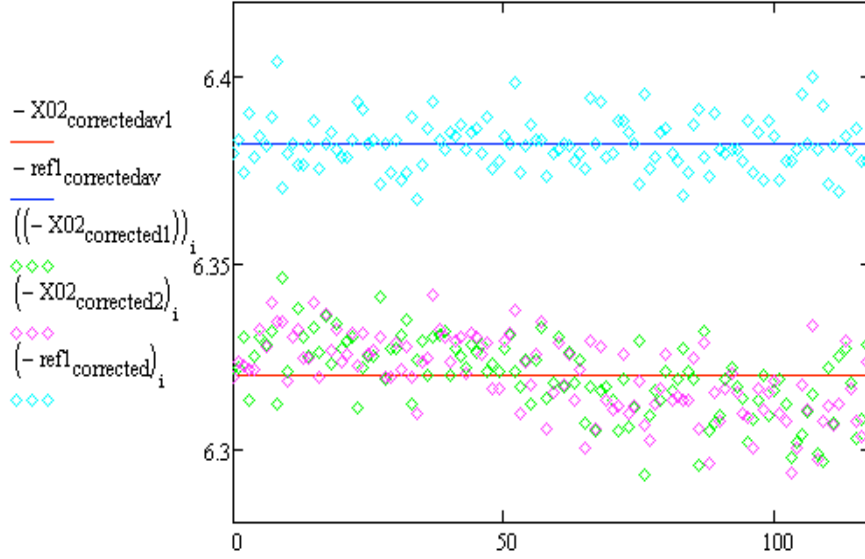


Figure 1.3: Original analysis of an ingress of XO-2b, from February 2009. This plot was made using Mathcad, with the x-axis indicating the image number, and the y-axis indicating the corrected, unnormalized magnitudes of the reference and target. The upper points plot the corrected magnitudes of the reference star in each image (relative to another reference star), with a line overplotted indicating the average relative reference magnitude over this set of images. The lower points plot the corrected magnitudes of the target star in each image, with an average line overplotted.

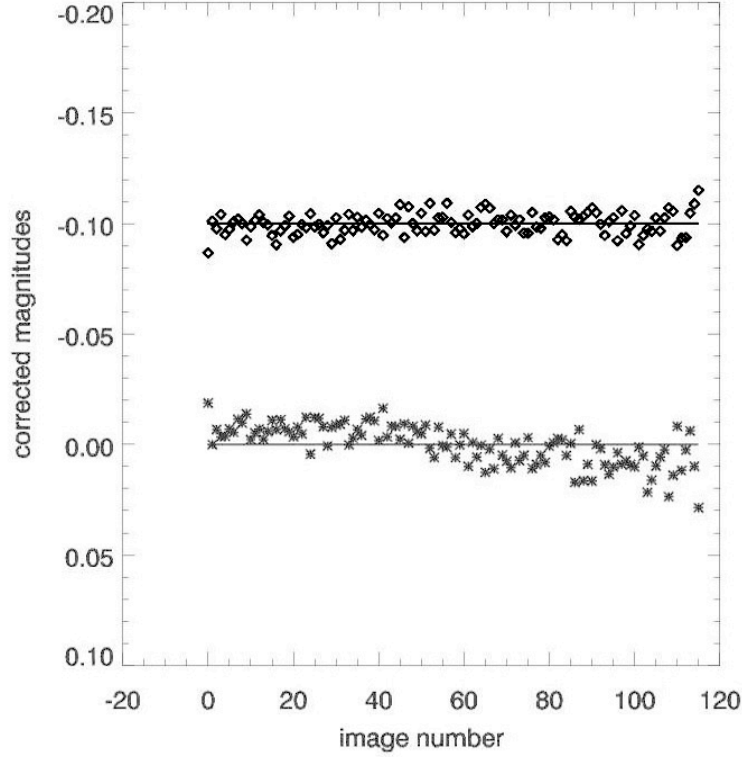


Figure 1.4: Result of IDL re-analysis of an ingress of XO-2b, from February 2009. The x-axis indicates the image number, and the y-axis indicates the corrected, normalized magnitudes of the reference (plus offset) and target. The upper diamonds plot the corrected magnitudes of the reference star in each image (relative to another reference star), with a line overplotted indicating the average relative reference magnitude over this set of images. The lower asterisks plot the corrected magnitudes of the target star in each image, with an average line overplotted.

Table 1.1: STEPUP Membership

Name	Affiliation	Grad. Yr.	Where they are now
Melanie Good	Grad Student	MS 2011	
Dr. Michael Wood-Vasey	Asst. Prof.		
Lou Coban	Observatory Manager		
Maya Hunt	Alumnus	BS 2010	Teaching physics in RI
Eric Roebuck	Alumnus	BS 2011	Grad School at Tufts U.
Chelsea Vincent	Undergrad	2012	
Gary Lander	Alumnus	BS 2011	Grad School at WVU
Korena Costello	Alumnus	BS 2011	L3 Brashear Optics
Gwen Weaver	Alumnus	BS 2010	Teaching physics in OK
Nelson Hua	Undergrad	2013	
Justine Drobitch	Undergrad	2012	
Kaitlyn Yoha	Engin. Undergrad	2012	
Aniket Patel	Undergrad	2014	
Linzi Webster	Undergrad	2014	
Shane Cerutti	Undergrad	2013	

2.0 METHODS

2.1 TELESCOPES/HARDWARE

By the time I was an undergraduate at the University of Pittsburgh, the heyday of active astronomical research at the Allegheny Observatory was largely over. There were a few lingering paid observers, but even these were no longer part of the staff by the time I began my graduate studies. Interestingly, the most recent field of research that had been taking place at the Allegheny Observatory was related to extrasolar planets. Throughout the career of Emeritus Professor George Gatewood, the Thaw telescope was used to astrometrically search nearby stars for signs of planetary companions, which would be evidenced by a periodic astrometric wobble in the position of the nearby star with respect to the “background” stars, which remain relatively fixed over short time spans of a couple decades or less.

In order to employ the transit method to detect extrasolar planets, I used the more modern 16” Meade LX-400ACF Keeler telescope. This telescope had replaced the 30” open-tube Keeler. The 16” is equipped with a Santa Barbara Instruments Group (SBIG) STL-6303E and a Jim’s Mobile Incorporated (JMI) zero image shift focuser with a smart focus attachment that allows computer control. As of January 2010, the Keeler telescope could be operated remotely from the astronomy computer lab in Allen Hall on the campus of the University of Pittsburgh. STEPUP members thus no longer need to have independent transportation to the Allegheny Observatory in order to use this instrument. The Keeler telescope is the instrument we have used to gather all of our observational data to date.

2.2 PIPELINE/SOFTWARE

After generalizing the basic IDL code to perform photometry, calculate relative flux, and plot the results, STEPUP members and I collaborated to transform the code into modular procedures, each of which could, in principle, be run independently if needed/desired. Thus we parceled off different tasks to independent procedures which were called from the main procedure shell. We also added several capabilities to our pipeline, including additional outputs of data files, in addition to the visual output of the lightcurve plot. These data files included two initial data files (one in fluxes of target and reference star and one in magnitudes of the same), two corresponding cut data files which had outliers cut from them, and two corresponding corrected data files (one in relative fluxes and one in relative magnitudes). The final result of our pipeline can be summarized in a flowchart of modules (see Figure 2.1)

The basic shell of the pipeline is called `generaltransit.pro`. From it, we first call up the master bias, master dark, and master flat procedures which take our calibration images and make masters of each type of calibration. After these masters are made, the shell calls up a procedure which takes the masters and performs image calibration and outputs these images to the directory `/home/depot/STEPUP/workspace` on the department's network of astronomy computers such as *diu* or *ra*. That procedure, in turn, calls up a procedure to determine the saturation level of the calibrated image and another procedure to take the calibrated images and perform astrometry on them, putting the wcs information into the header of the image file. The astrometry is accomplished with *imwcs*, part of the wcs tools developed by Doug Mink at the Harvard-Smithsonian Center for Astrophysics and publicly available on the wcstools website¹. *imwcs* can take an input catalog of stars and compare them to another catalog of stars to find an astrometric solution. In our case, we use star catalogs downloaded from Simbad² and compare them to the catalog of stars consisting of

¹<http://tdc-www.harvard.edu/wcstools/>

²<http://simbad.u-strasbg.fr/simbad/>

stars found by the *find* command in IDL³, which is executed prior to using *imwcs* in this module.

After the astrometry has been performed, the shell calls up a procedure to read the date from the image header (in Universal Time, UT⁴ and convert it to Geocentric Julian Date, GJD⁵. The next procedure the shell calls performs all the photometry on the target and two reference stars, outputting arrays of target and reference fluxes as well as errors for the target and reference fluxes. A simple procedure called from the shell then converts these fluxes to magnitudes, and then the shell outputs two initial data files, one which uses the flux arrays and the other which uses the magnitude arrays. The columns in these files are: GJD, target magnitude or flux, reference 1 magnitude or flux, reference 2 magnitude or flux, error of the target (in magnitude or flux), WCSSEP (a measure of the quality of the astrometric solution), WCSmatch (a measure of how many stars were matched in making the astrometric solution), WCSnref (the number of reference stars used in making the astrometric solution), error of reference 1 (in magnitude or flux), and error of reference 2 (in magnitude or flux).

Next, the shell calls up a procedure which performs differential photometry, calling it once for magnitudes and once for fluxes. This procedure, *gtcorrection.pro* then calls up a procedure that cuts any nonsensical data (such as a value of 99 for magnitude), and then outputs two sets of a cut data file and a corrected data file (one in magnitudes, the other in fluxes). These files contain the same basic columns as the initial data files, except that they are in normalized, relative fluxes or magnitudes.

Finally the shell calls up its final procedure, *plotlc.pro*, which outputs two sets of plots, one in relative magnitude of the target vs. GJD and the other in relative flux of the target vs. GJD. In addition, this procedure also outputs zoomed-in versions of each of these plots.

The pipeline can also be started at several different points so that we can bypass com-

³<http://idlastro.gsfc.nasa.gov/ftp/pro/idlphot/find.pro>

⁴Universal Time is measured from 0 hours at midnight in Greenwich, England, and is based on the mean solar day (<http://tycho.usno.navy.mil/systime.html>).

⁵Geocentric Julian Date, also known simply as Julian Date refers to the time elapsed since noon on January 1, 4713 B.C. as specified by the Julian calendar. This time acts as a zero point from which other times are measured, with 1.0 equal to one day (Carroll and Ostlie, 2007, pp. 13-14).

plete re-analysis if desired. For example, if we would like to begin with the calibrated images instead of re-doing the image calibration, we can begin at that point in the flowchart. In addition most modules can be used independently. A convenient application of the independent use of an individual module is that if we already have initial photometry on a data set and would like to calculate relative photometry and output this information in a data file. In that case, we can simply run `gtcorrection.pro` by itself, inputting the initial photometry file.

This modular nature has allowed our pipeline to be both comprehensive and flexible. Such comprehensiveness has generally given us the ability to analyze data efficiently, and such flexibility has proven to be very valuable when encountering issues that need troubleshooting, as well as very utilitarian when we wish to focus on a particular aspect of pipeline improvement.

All the code we have written is stored on the astronomy's network of computers in the directory `/home/depot/STEPUP/code`. Our raw data is stored both on the Allegheny Observatory computer, and on the department network of computers. At first we stored the raw data in `/home/diu-data/STEPUP/raw` and when we exhausted the space there we stored subsequent raw data in the directory `/home/depot/STEPUP/raw`. Our code automatically searches for raw data in the former of these two directories and if it does not find the specified target and date there, it searches in the other directory. This allows us to leave the old raw data in place and no matter which directory a set of data is stored in, our code can find it. We also check our code into an svn repository⁶:

`/home/bruno/users/mlg52/repository/myrepository.`

Svn is a version control software that allows us to keep track of changes made to our code. Utilizing svn for version control allows us not only to log changes we make to the code, but to revert to previous versions of the code if warranted. With multiple members of STEPUP revising the code, this helps us better track our changes and improvements. Svn acts somewhat like a library wherein you can “check out” a set of code from the repository

⁶<http://subversion.apache.org/>

and check it back in by “committing” the revised file, along with a log message describing the changes made. If in the meantime, someone else has committed a change to the current version, the conflict will be shown and will need to be resolved in order to commit. This prevents one person from undoing a revision another person made. Furthermore, once you initially check out the project, you need only “update” your code files to the current version. From any of the astro network of computers in the department, one can check out the current version of the code by typing from the command line:

```
$ svn checkout file:///home/bruno1/users/mlg52/repository/myrepository/code
```

2.3 PHOTOMETRY

2.3.1 STEPUP Aperture Photometry

The 16” Keeler telescope is equipped with a Johnson-Cousins UBVRI filter system, and typically our data is taken using the R band filter. STEPUP members follow a checklist protocol for collecting data which specifies this filter. Also on the checklist is the procedure for selecting exposure times. This procedure is simply based upon optimizing our signal to noise ratio by selecting an exposure time which results in the number of counts received by our target star being between 50 and 60 percent of the saturation value. For the majority of our targets, this exposure time is usually between 30 and 60 seconds.

Within the photometry module of our pipeline we perform aperture photometry in IDL with the *aper* command⁷. This command allows us to specify the radius of the star aperture, as well as the radii of the inner and outer sky annuli, and, using these radii, it measures the brightness of the star compared to the surrounding sky. These radii are currently set at 10, 15, and 35 pixels respectively, as we have found that these radii work well for the majority of our targets. Originally the star radius had been set at 7 pixels since this seemed to work

⁷<http://idlastro.gsfc.nasa.gov/ftp/pro/idlphot/aper.pro>

for our first data set, the February 6, 2009 transit of XO-2b. However, due to some out-of-focus data in our HD80606b campaign, the sky radius was increased to 10 pixels. I later examined what star radius would yield optimal signal-to-noise for both a single image taken from both a night of good seeing (when the point spread function, psf, was fairly sharply defined) and a night of poor seeing (when the psf was more broadly defined). For the first case the maximal signal-to-noise is achieved with a 5 pixel star radius and for the second case with an 8 pixel star radius. However, for several sets of data, we found that using a star radius smaller than 10 pixels, while sometimes yielding lower individual errors, resulted in more of a photometric spread in our output files. The exact reason for this is currently being investigated by STEPUP members. (See Appendix B) Additionally, one of our next goals will be to calculate the maximum signal-to-noise aperture radius within our pipeline so that the radii are chosen to be optimal for the set of data being analyzed.

2.3.2 Theoretical Flux Received During Planetary Transit

The flux we receive on Earth from a star located at a distance d from us is equal to that star's luminosity divided by the area of a huge imaginary sphere of radius d upon whose edge we are sitting:

$$F_* = \frac{L}{4\pi d^2} \quad (2.1)$$

If we think of the star as a circular disk of area πR_*^2 , the Stefan-Boltzman Equation allows us to replace the luminosity with $L = \pi R_*^2 \sigma T^4$ where R_* is the radius of the star and T is the surface temperature of the star. Thus the flux of the star can be expressed as

$$F_* = \frac{R_*^2 \sigma T^4}{4d^2} \quad (2.2)$$

When a planet is blocking the light coming from the star, and if we make the approximation that the distance from earth to the star is the same as the distance from earth to the planet orbiting the star, we can then think of the light radiating out from the

partially-blocked star as a circular disk being blocked by a smaller circular disk. Subtracting this smaller circular disk from the larger one, the Stefan-Boltzman Equation becomes: $L = (\pi R_*^2 - \pi R_p^2)\sigma T^4$. Of course to be precise, the planet has some surface brightness of its own, so it is not entirely taking all of the brightness to zero in the small portion of the star that it is "blocking." However, since, in general, planets have a much lower temperature than the stars they orbit, a planet's surface brightness (especially in visible wavelengths) is much much smaller than that of the star, making the preceding a good approximation. This means that during a transit (ie. when the planet is blocking some flux from the star), the flux we receive from the star is well approximated by:

$$F_{*p} = \frac{(R_*^2 - R_p^2)\sigma T^4}{4d^2} \quad (2.3)$$

We can then define a quantity, $\Delta F = F_* - F_{*p}$. Now we can express the ratio of ΔF to F_* as:

$$\frac{\Delta F}{F_*} = \frac{(R_*^2 - R_*^2 + R_p^2)\sigma T^4}{4d^2} \frac{4d^2}{R_*^2\sigma T^4} = \frac{R_p^2}{R_*^2} \quad (2.4)$$

So the "depth" of a planetary transit (ie. how much the star dims compared to its out-of-transit brightness) tells us about the ratio of the planet radius to the star radius. Given Equation 2.4, we can ask ourselves what transit depth we would expect like for an Earth-analog planet, and using Equation 1.1 we can determine the transit probability for such an object. Plugging in values for the radii of the Earth and of the Sun into Equation 2.4 we conclude that a transit depth due to an Earthlike planet transiting a Sunlike star would be: $\frac{\Delta F}{F_{\text{sun}}} \approx 0.0084\%$. Taking $R_{\text{sun}} + R_{\text{earth}} \approx R_{\text{sun}}$, and using Equation 1.1, an Earthlike planet orbiting a Sunlike star at 1AU would have a probability of transiting of $\sim 0.3\%$. These numbers help explain why a planet as small as the Earth and orbiting at a similar semi-major axis as the Earth has not yet been found.

Nevertheless, as discussed in Section 1.2, the NASA Kepler mission has the ability to detect an Earth-analog. Indeed, Kepler is capable of detecting a transit depth as shallow as 0.003% (Jenkins et al., 2010). And to overcome the low probability of transit, Kepler is

targeting 100,000 main sequence stars (Jenkins et al., 2010). Thus just based on the sheer number of targets, Kepler expects to find a handful of Earthlike planets by the completion of its mission.

2.3.3 Corrected Photometry

The detection of extrasolar planets by the transit method relies upon calculating relative photometry. What this means is that we look for any changes in brightness of our target star *relative* to other, reference stars in the image. This allows us to dismiss any changes in brightness which occur both to target and reference stars as being due to changes in observing conditions or similar such effects, and instead identify changes in brightness that are unique to the target star itself.

As we know from the previous section, the ratio of flux during a transit to that out of a transit is simply related to the square of the ratio of the planetary radius to the stellar radius (Eq. 2.4).

In reality though, not all the flux emitted from the star reaches our detector perfectly due to the atmosphere of earth, instrumental instabilities, inconsistent CCD response, dark current noise, etc. If we assume the flux we actually observe from our target star, F_{to} has been reduced by some factor, η due to all of these sources of noise, we can write that $F_{to} = F_{t*}\eta$ where η is a number less than one and F_{t*} is the true flux received by the target (ie. what we would measure if there were no sources of noise). Here is the beauty of relative photometry: If we don't care about knowing the absolute brightness of the star, and if we assume that the unspecified sources of noise affect all stars in the image the same way, we can cancel η out by looking instead at the flux of our target relative to the flux of a reference star or the average flux of many reference stars, F_r . Thus the relevant quantity is:

$$\frac{F_{to}}{F_{ro}} = \frac{F_{t*}\eta}{F_{r*}\eta} = \frac{F_{t*}}{F_{r*}} \quad (2.5)$$

Whatever quantity this gives us should, in principle, remain constant in time if no other effects besides η cause any stars to change brightness. Thus if we notice a periodic dip in

brightness followed by an increase in brightness to the original value, this could be taken as a sign that something unseen, such as a planet, crossed in front of the star and blocked out a portion of its light for a brief time. While this is not the only possible explanation for periodic changes in brightness, such a detection is very powerful evidence of a planetary companion orbiting the star if other explanations for the brightness change can be ruled out.

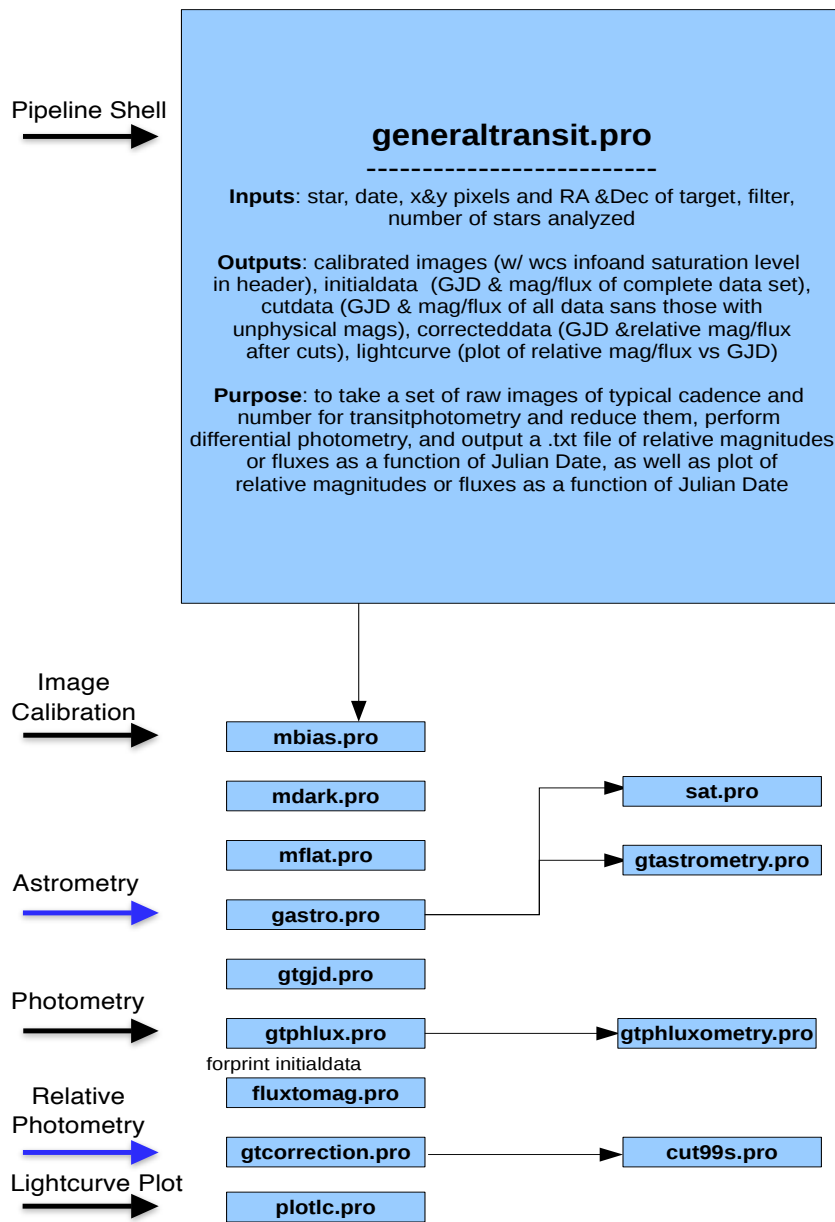


Figure 2.1: Pipeline Flowchart. The arrows indicate the functions performed at various points in the pipeline. “Astrometry” and “Relative Photometry” are indicated in blue arrows, since these are alternate entry points into the pipeline. If we already have good image calibration, for example, we can begin our analysis at the astrometry entry point. Or if we already have a good initial data file, we can enter the pipeline at the relative photometry calculation.

3.0 KNOWN TRANSITING PLANETS

3.1 PLANNING FOLLOW-UP OBSERVATIONS

One way STEPUP contributes to extrasolar planet research is through follow-up observations of known transiting planets. The convenient aspect of observing known transiting planets is that we can strategize a timeframe of when to observe them since the times that they are expected to transit are, in general, known. Indeed, expected transit times are made publicly available through resources such as Transitsearch¹ and the Exoplanet Transit Database, ETD²(Poddaný et al., 2010). (See Appendix A for details on our strategy for utilizing Transitsearch and ETD in planning our follow-up observations of known extrasolar planets). Both of these tools have advantages and disadvantages.

Transitsearch is a website run by Prof. Gregory Laughlin at University of California Santa Cruz. Included on this website are the coordinates of each target, the depth of the transit and when a transit is expected to take place (in Universal Time and Heliocentric Julian Date). This site includes many known extrasolar planets, not all of which are known to transit. Those that are not yet known to transit are planets that were discovered via radial velocity, and these particular planets are listed along with their geometrical probability of transiting on Transitsearch. The inclusion of these planets and their expected possible transit times allows observers to strategize when to search for signs of a transit. If a transit is found it allows for the breaking of the $M_p \sin i$ degeneracy and allows us to take i to be fairly close

¹www.transitsearch.org

²<http://var2.astro.cz/ETD/index.php>

to 90° and make the accurate approximation that $\sin i = 1$ and thus that $M_p \sin i = M_p$. In this case, by combining this with the planet to star radius ratio found from the depth of transit (Eq. 2.4) all we need is the radius of the star to determine the radius of the planet and thus determine the density of the planet by using $M_p \sin i = M_p$ for the mass of the planet.

Consequently, Transitsearch is a useful tool for photometrically following up on planets not yet known to transit. Furthermore observers can prioritize their targets based on their probability of transiting and the depth of the expected transit. The main disadvantage of Transitsearch is that, while it lists the coordinates of the target, users must find an image of the star field from another source in order to pinpoint more exactly which star is the target in their field of view.

On the other hand Exoplanet Transit Database (ETD) does include field images of each target star with the target clearly marked, in order to aid in identifying it. Like Transitsearch, ETD includes the expected transit time (in Universal Time), coordinates of each target and depth of the transit. However, ETD only includes targets that are known to transit, so it is not helpful in providing information to follow up on searching for transits of planets that are not yet known to transit. Still if our objective is to provide follow-up data for known transiting systems ETD is a very useful tool for planning our observing (Poddaný et al., 2010).

In addition to these websites STEPUP has also planned follow-up transit observing based on information from collaborators. For example, for the HD80606b campaign, the collaboration organizer, Josh Winn, had predicted the mid-transit time for the night our collaboration was to observe (Shporer et al., 2010; Winn et al., 2009). Another example is our SDSS-III MARVELS targets. The identity of these targets is confidential, since they are planetary candidates awaiting confirmation. Thus for MARVELS targets, Transitsearch and ETD will not help us in planning observing. Occassionally we are given some information from the MARVELS team about expected transit times, but since the targets are generally on short-period orbits of a couple of days, there is not much to gain by planning out exact

observing runs over simply observing a priority target all night each clear night.

Once we have planned our observing and taken our data, we run it through our analysis pipeline and look for signs of a transit. In addition to simply plotting our corrected brightness vs. time, for known transiting planets, we can use ETD to upload our corrected data files for more exact fitting (see Section 3.3). Even if the planet is not yet known to transit, if we know certain predicted parameters about the planet and star, we can use the Transit Analysis Package³ to further search for signs of a transit. In addition, a couple STEPUP members have more recently been working to develop a simple procedure to perform a chi-square test which will flag data sets that potentially include a transit.

Finally, we submit our data to various scientific entities. If it is a known transiting planet we can submit our data to be publicly available on ETD. Or, if it is a collaboration such as the HD80606b campaign or the SDSS-III MARVELS targets, we submit our data for use with the collaborative observing effort. This has resulted in STEPUP contributing to one paper thus far (Shporer et al., 2010) with another paper (regarding a MARVELS target) currently in the making. The MARVELS paper will discuss a target dubbed “MC002” for “MARVELS Candidate 2,” since its identity is currently confidential. The paper will report on the radial velocity findings of the MARVELS observations, and include the photometric findings that STEPUP has contributed to the study of this target.

3.2 BRIEF DESCRIPTION OF OBSERVED TARGETS

The targets STEPUP has observed, including basic information about them and problems we encountered can be summarized as follows:

³<http://ifa.hawaii.edu/users/zgazak/IfA/TAP.html>

3.2.1 HAT-P-1b

HAT-P-1b is a 0.524 Jupiter-Mass, 1.217 Jupiter-Radius planet orbiting a G0V star 139 pc away at RA: 22:57:47 Dec:+38:40:30. The star is in a close binary system. HAT-P-1b orbits at a semi-major axis of 0.05535 AU, with an eccentricity < 0.067 and an orbital period of 4.4652934 days.⁴ STEPUP has observed this target once in December 2009. This data set might include a partial transit. GJD=2455167.67, which appears to look like a possible mid-transit time, closely coincides with the predicted mid-transit time for HAT-P-1b, being off by only about 8 min. However, this data set suffers from poor tracking and our limited ability to obtain accurate brightness measurements for such a close binary star system using aperture photometry, so it is unclear if we can make any statement about having captured a transit in this data set. The lightcurve can be seen in Figure E1.

3.2.2 HAT-P-9b

HAT-P-9b is a 0.67 Jupiter-Mass, 1.4 Jupiter-Radius planet orbiting an F star 480 pc away at RA: 07:20:40 Dec:+37:08:26. HAT-P-9b orbits at a semi-major axis of 0.053 AU, with an approximately zero eccentricity and an orbital period of 3.922814 days.⁵ STEPUP has observed this target once in November 2009. Unfortunately, the FWHM for this data set was 10.219, the largest of any of our data sets, making accurate aperture photometry difficult to obtain, and resulting in very poor RMS. See table 3.2.

3.2.3 HAT-P-13b,c

HAT-P-13b is a 0.85 Jupiter-Mass, 1.28 Jupiter-Radius planet orbiting a GIV star 214 pc away at RA: 08:39:32 Dec:+47:21:07. HAT-P-13b orbits at a semi-major axis of 0.0426 AU, with an eccentricity of 0.0142 and an orbital period of 2.916243 days. HAT-P-13c is a 14.5 Jupiter-Mass planet orbiting the same star. HAT-P-13c orbits at a semi-major axis of 1.186

⁴<http://exoplanet.eu/planet.php?p1=HAT-P-1&p2=b>

⁵<http://exoplanet.eu/planet.php?p1=HAT-P-9&p2=b>

AU, with an eccentricity of 0.666 and an orbital period of 448.2 days.⁶

STEPUP has observed this target eleven times in March and April 2010. At the time, STEPUP was searching for signs of a transit of HAT-P-13c, which had been discovered by Bakos et al. (2009) but not yet known to transit. Thus our lightcurves were not necessarily expected to coincide with a transit of HAT-P-13b. Nevertheless, given its short orbital period and the frequency with which we were observing this target, there was definite potential for us to find a transit of HAT-P-13b in our data. Had we found such a transit, we could have explored any signs of transit timing variations which might have been due to the presence of HAT-P-13c.

Unfortunately, tracking, guiding, and focussing issues consistently plague most of these data sets as is summarized in table 3.2. In addition, on many nights, the telescope was left taking images after observers retired for the night. The rationale behind this practice is to maximize the amount of data one observer can collect. This can yield reasonable results provided conditions do not significantly worsen, and focus and guiding are maintained; however, one or more of these criteria were typically not met, resulting in significant scatter towards the end of many data sets, in addition to the previously mentioned factors that contributed to large FWHM, and poor RMS in general. Three nights of data have not been successfully analyzed through our pipeline due to these sorts of problems. Our best lightcurve is Figure E6 and consistent with constant flux, showing no signs of transit of either planet.

3.2.4 HD80606b

HD80606b is a 3.94 Jupiter-Mass, 0.921 Jupiter-Radius planet orbiting a GV star 58.4 pc away at RA: 09:22:37 Dec:+50:36:13. HD80606b orbits at a semi-major axis of 0.449 AU, with an eccentricity of 0.93366 and an orbital period of 111.43637 days.⁷ STEPUP has observed this target three times in September 2009, January 2010 and April 2010. This

⁶<http://exoplanet.eu/planet.php?p1=HAT-P-13&p2=b>

⁷<http://exoplanet.eu/planet.php?p1=HD+80606&p2=b>

target will be discussed at length in Chapter 4.

3.2.5 TrES-2

TrES-2 is a 1.253 Jupiter-Mass, 1.169 Jupiter-Radius planet orbiting a G0V star 220 pc away at RA: 19:07:14 Dec:+49:18:59. TrES-2 orbits at a semi-major axis of 0.03556 AU, with an approximately zero eccentricity and an orbital period of 2.470614 days.⁸ I observed this target when it was out-of-transit, as an undergraduate in October 2008, and STEPUP has observed this target once in August 2010. See Figures E14 and E15.

3.2.6 WASP-2b

WASP-2b is a 0.847 Jupiter-Mass, 1.079 Jupiter-Radius planet orbiting a KIV star 144 pc away at RA: 20:30:54 Dec:+06:25:46. WASP-2b orbits at a semi-major axis of 0.03138 AU, with an approximately zero eccentricity and an orbital period of 2.470614 days.⁹ STEPUP has observed this target once in October 2010.

3.2.7 WASP-3b

WASP-3b is a 2.06 Jupiter-Mass, 1.454 Jupiter-Radius planet orbiting a F7V star 223 pc away at RA: 18:34:32 Dec:+35:39:42. WASP-3b orbits at a semi-major axis of 0.0313 AU, with an approximately zero eccentricity and an orbital period of 1.8468372 days.¹⁰ STEPUP has observed this target once in May 2011.

3.2.8 XO-2b

XO-2b is a 0.57 Jupiter-Mass, 0.973 Jupiter-Radius planet orbiting a K0V star 149 pc away at RA: 07:48:07 Dec:+50:13:33. XO-2b orbits at a semi-major axis of 0.0369 AU, with an

⁸<http://exoplanet.eu/planet.php?p1=TrES-2&p2=>

⁹<http://exoplanet.eu/planet.php?p1=WASP-2&p2=b>

¹⁰<http://exoplanet.eu/planet.php?p1=WASP-3&p2=b>

approximately zero eccentricity and an orbital period of 2.615838 days.¹¹ I observed this target once as an undergraduate, in February 2009.

3.3 KNOWN TRANSIT ANALYSIS

Our earliest analysis was done on known transiting planets, and our analysis at this time consisted of plotting the relative brightness vs. time of our target compared to two reference stars. (For examples, see Figure 3.1). Though we generated output data files listing the points on the plots as columns, we did not employ any sort of fitting on our own. However, we did submit some of our data to the Exoplanet Transit Database, ETD¹² which performed more sophisticated analysis and fit of our data. For example Figure 3.2, Figure 3.3, Figure 3.4, and Figure 3.5 summarize the results of ETD analysis of our observations of TrES-2b taken on August 18, 2010. As can be seen from Figure 3.5 the geometric values implied by our data are within the errors of the catalogue data. Most other analysis results also agree well with existing data. In Figures 3.6, 3.7, and 3.8 our data point is seen in blue. It not only agrees well with other data points plotted, but ETD’s “data quality indicator” suggests it is good quality data: a 2 on a scale of 1 to 5 with 1 being the best, as is seen on the insets of Figures 3.6, 3.7, and 3.8.

When we strategically planned our observing of known transiting planets to coincide with predicted transit windows, we generally knew there would be a transit somewhere in the data sets. Moreover we knew about what time to expect the transit to take place. Thus these observations of known transiting planets served to help us confirm the success of our basic analysis procedures if we were able to reproduce a lightcurve of the right depth and at the right time. More recently a STEPUP member has taken on the challenge of working to develop a box fitting algorithm for more sophisticated fitting of our data. Furthermore, obtaining out-of-transit data has served to verify that our photometry measurements indeed

¹¹<http://exoplanet.eu/planet.php?p1=X0-2&p2=b>

¹²<http://var2.astro.cz/ETD/index.php>

yield a constant relative flux, as well as to begin to investigate possible additional transiting planets in the target system, such as HAT-P-13c.

In addition, our contributions to the Exoplanet Transit Database served the scientific community in adding to the publicly available follow-up data on transiting extrasolar planets. Indeed, the Exoplanet Transit Database has been used by scientists searching for phenomena such as transit timing variation ([Maciejewski et al., 2010](#); [Christiansen et al., 2011](#)). Finally, one case study in particular allowed us to contribute important data to a collaborative effort to observe the transit of a known planet, namely HD80606b. The HD80606b analysis was more rigorously treated by the collaboration at large, and is detailed in Chapter 4: HD80606b Campaign and in the paper that resulted from the collaborative observing effort ([Shporer et al., 2010](#)).

3.4 CONCLUSIONS ON KNOWN TRANSITING PLANETS

Much can be learned from our observations of known transiting planets. First, targeting these systems helps us confirm our techniques and analysis. For the systems we have studied, we have obtained results that agree with predictions for values such as transit depth and timing. This is especially useful for new members of STEPUP who are just learning the principles of the transit technique. Understanding what we are aiming for then helps STEPUP members both in maintaining quality observational results and in developing software improvements. Indeed our August observations of TrES-2 have become our benchmark for a quality lightcurve and for testing new improvements made to our analysis procedures. Also, in developing fitting procedures of our own, our TrES-2 observations give us a quality test case to run such procedures on, since we have a clear, comprehensive transit and we can directly compare the results of any fitting procedure we develop to the fit done using ETD ([Poddany et al., 2010](#)).

Second, we can contribute to various collaborations and scientific entities. For example,

looking for long-term patterns in transit timing or duration becomes more useful with tools like ETD which allow for using archived data such as ours. Or when observing on long-period transits, it is often useful to collaborate with other observatories to maximize coverage of the transit, as we did for the case of HD 80606b.

Finally, our observations of known transiting planets give us the opportunity to move forward in understanding our sources of errors and to optimize our results. One STEPUP member used known transiting planet data to investigate the gain we use to better pinpoint this contribution to our error budget. Moreover, Appendix B illustrates how we improved the spread of our data in our TrES-2 lightcurve by changing the choice of inner and outer sky radii in our aper command.

These are some of the highlights of the many practical and scientific applications for our observations of known transiting planets. Follow-up observations are a very important aspect of the study of extrasolar planets, both to confirm what we know and to search for clues that might point towards what we do not yet know. Therefore, observing such known systems will continue to be an ongoing endeavor for STEPUP research.

For a summary of all known transiting targets observed and number of data sets analyzed for each target see table 3.1. For a summary of number of images, FWHM, and RMS of each data set, see table 3.2. For example images of all transiting targets observed, see Appendix C. Finally lightcurves of these targets can be found in Appendix E, and data files of the photometry for these data sets can be found in Appendix F.

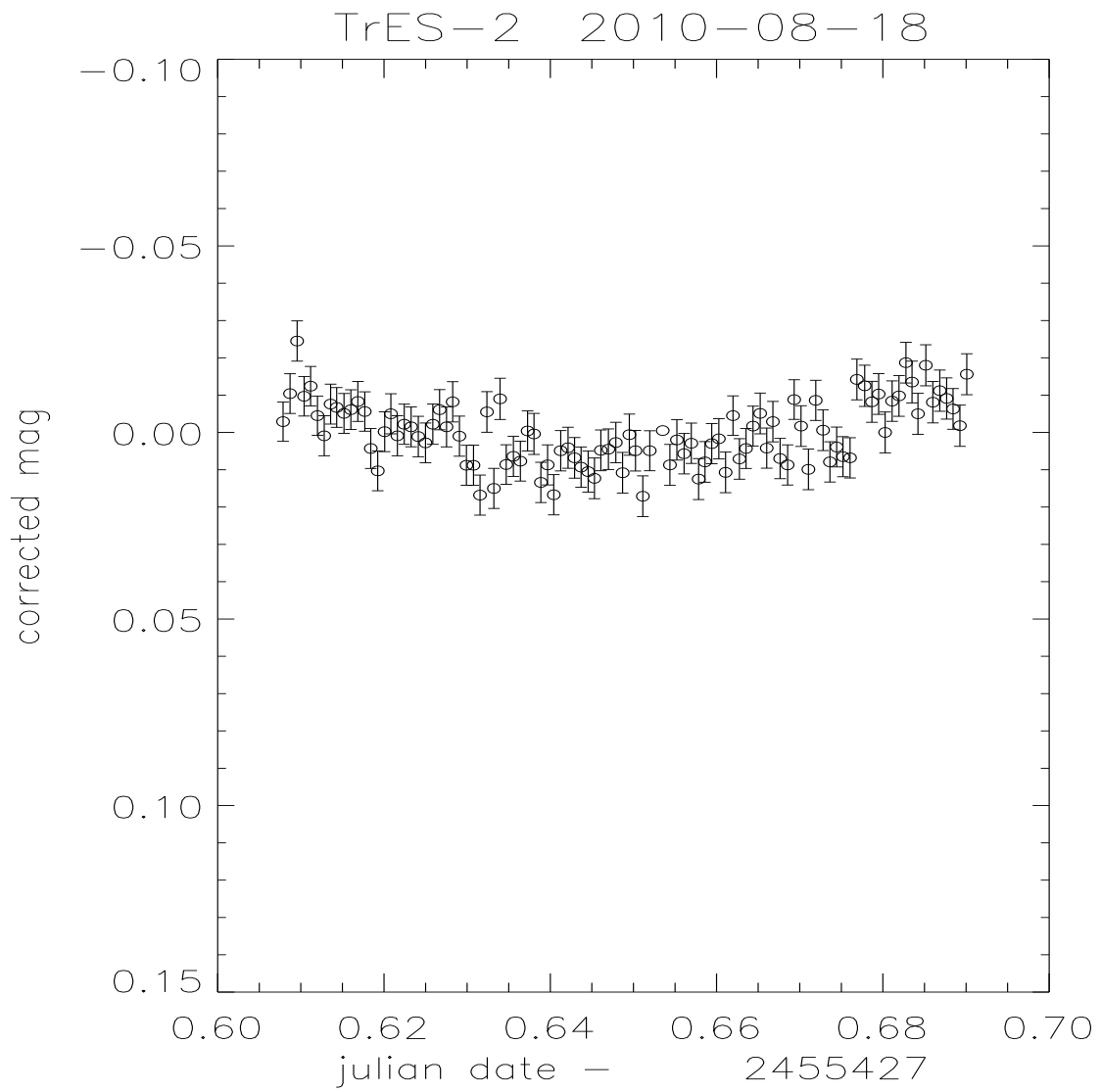


Figure 3.1: STEPUP Plot of relative brightness vs. Julian date for transit of TrES-2b from August 18, 2010

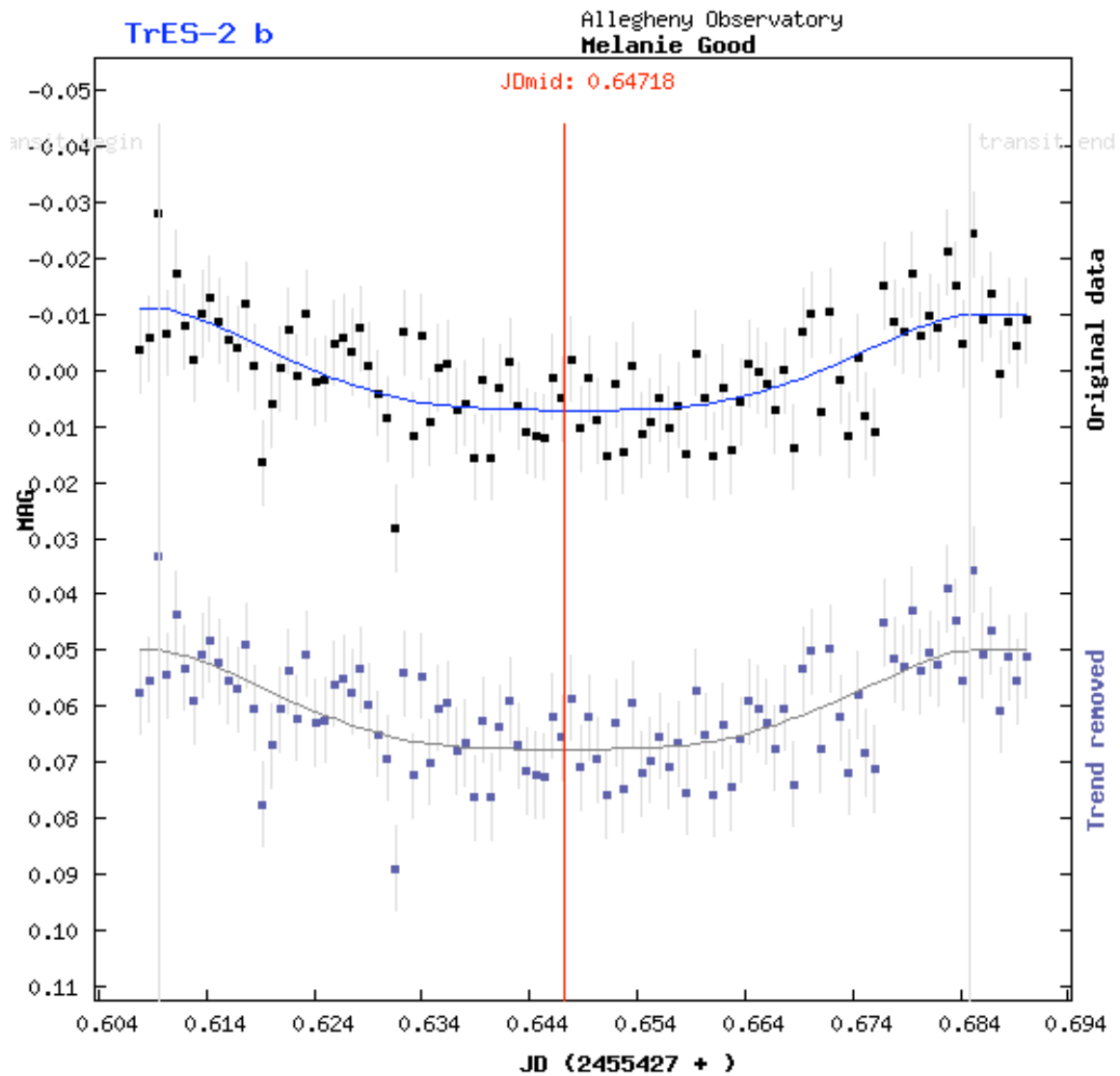


Figure 3.2: Transit of TrES-2b from August 18, 2010, as fitted by ETD, <http://var2.astro.cz/ETD/index.php> The lower “trend removed” lightcurve appears on all fitted lightcurves submitted to ETD. This lightcurve corrects for systematic errors (Poddany et al., 2010).

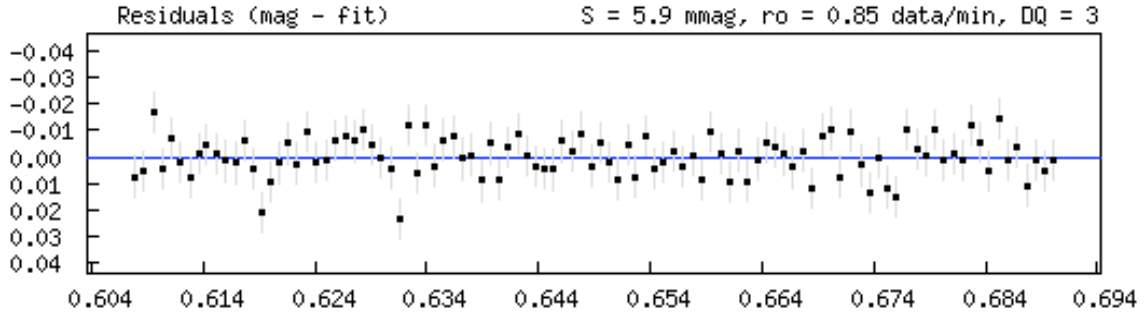


Figure 3.3: Residuals of August 2010 TrES-2b transit as calculated by ETD ([Poddaný et al., 2010](#)).

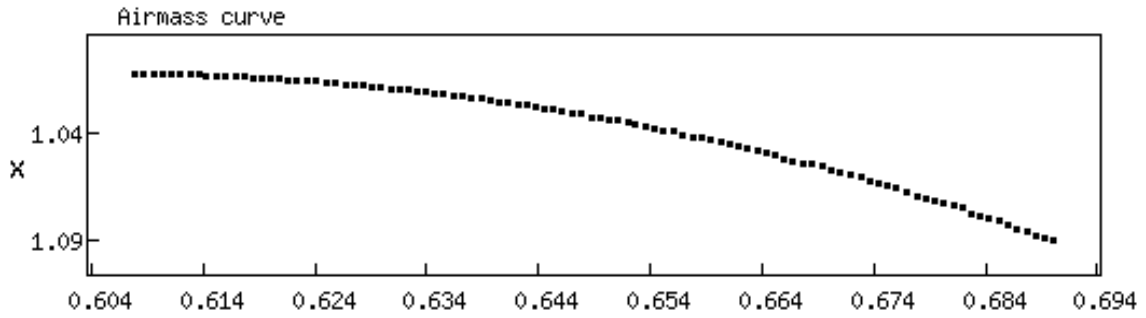


Figure 3.4: Airmass calculated by ETD for August 2010 TrES-2b transit ([Poddaný et al., 2010](#)).

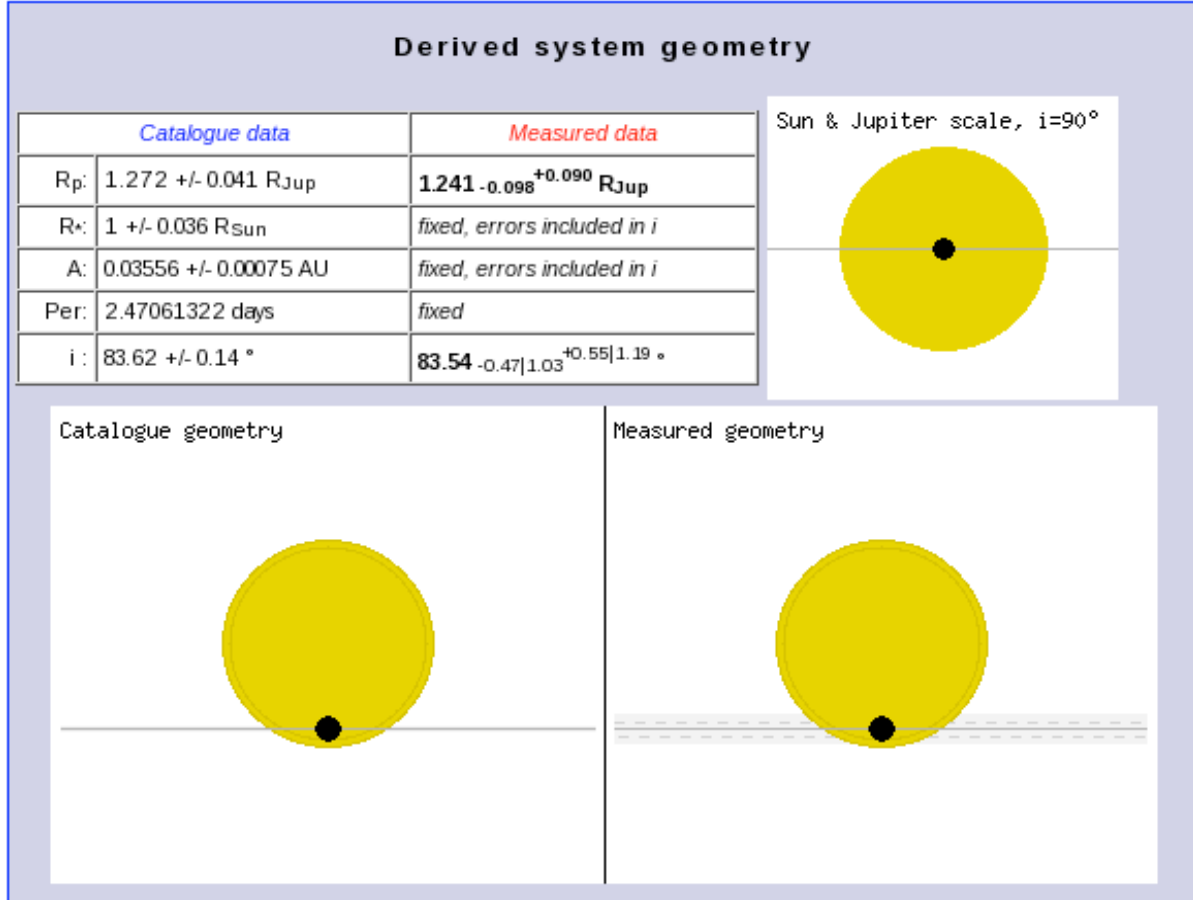


Figure 3.5: ETD-derived geometry for TrES-2 system using STEPUP August 2010 data (Poddaný et al., 2010).

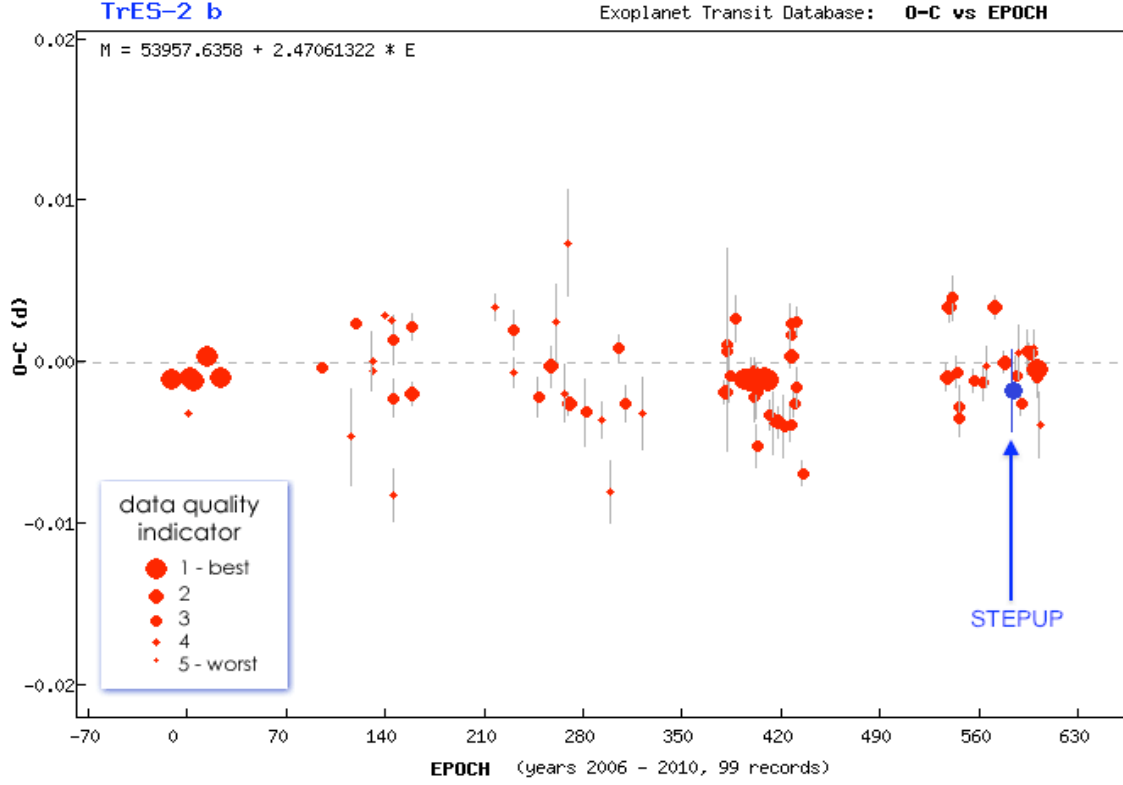


Figure 3.6: ETD O-C plot of TrES-2b with submitted observations from various observatories. STEPUP data point is labeled and appears in blue with error bars. The size of the data point represents its quality as judged by ETD and explained on the inserted box. STEPUP data is a 2 on a scale of 1 to 5, with 1 being the best. The vertical axis represents the “observed minus calculated” value for the mid-transit time, with zero indicating that the mid-transit time occurred at the same time as was calculated. A dashed horizontal line at $O-C = 0$ is overplotted. A discrepancy from this line in the data could indicate a transit-timing variation, which has implications for the nature of the system in question, such as possibly indicating the presence of additional planets not yet detected (Poddany et al., 2010).

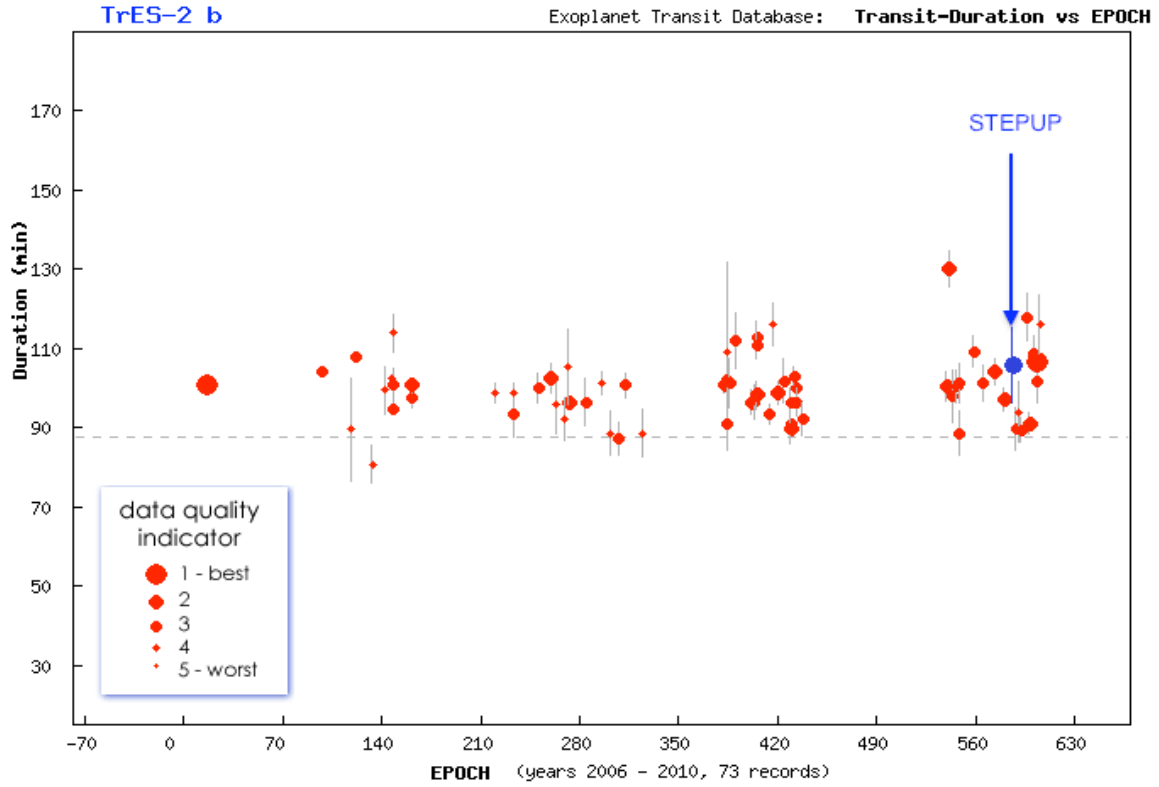


Figure 3.7: ETD transit duration plot of TrES-2b with submitted observations from various observatories. STEPUP data point is labeled and appears in blue with error bars. The dashed horizontal line indicates the calculated transit duration (Poddaný et al., 2010). Many observations seem to imply a longer duration than expected. Transit-duration variation might indicate that the accepted orbital parameters are not yet precisely correct or even something as exotic as the presence of an exomoon, though this is not likely to be the case for TrES-2b, since it was studied in detail by Kepler and not shown to exhibit signs of an exomoon (<http://www.homepages.ucl.ac.uk/~ucapdki/tres2.html>)

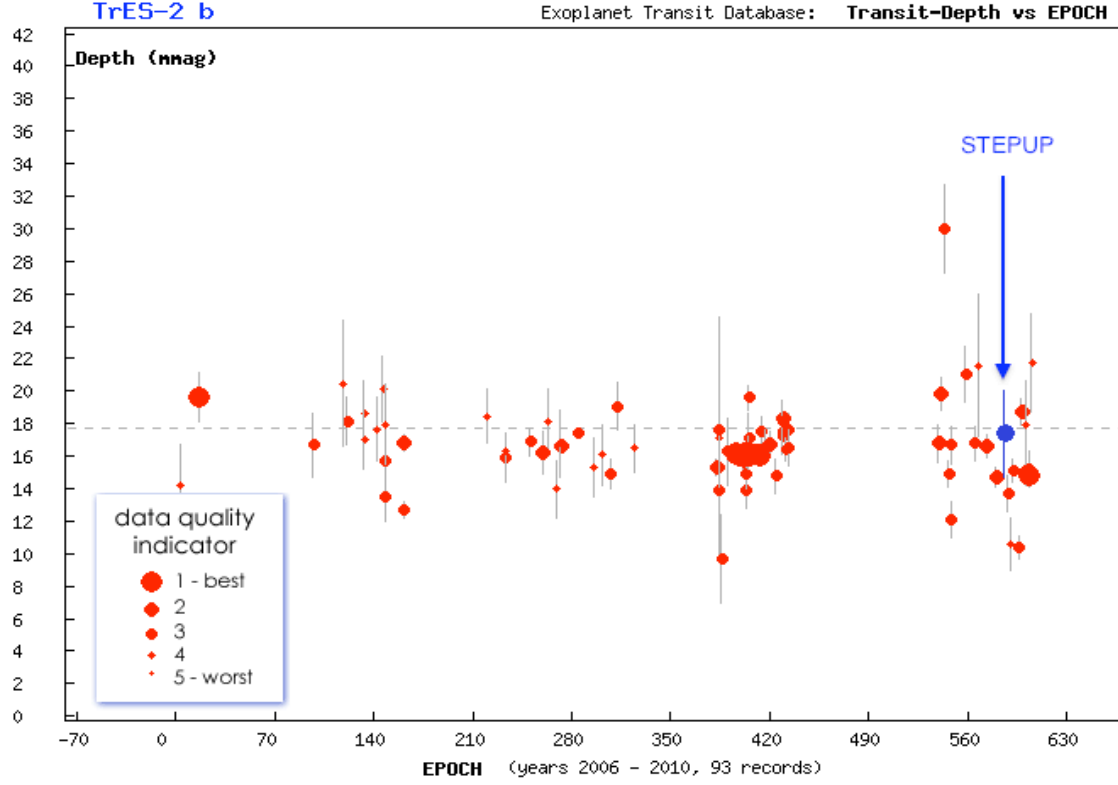


Figure 3.8: ETD transit depth plot of TrES-2b with submitted observations from various observatories. STEPUP data point is labeled and appears in blue with error bars. The dashed horizontal line indicated the expected transit depth ([Poddany et al., 2010](#)).

Table 3.1: Summary of Known Transiting Targets Observed

Target	No. Data Sets	Beginning	Ending	Stellar Mag	Spectral Type
HAT-P-1	1	2009-12-01	2009-12-01	10.4	G0V
HAT-P-9	1	2009-11-03	2010-04-26	11.27	F
HAT-P-13	11	2010-03-31	2010-04-27	10.62	GIV
HD80606b	3	2009-09-23	2010-04-29	8.93	GV
TrES-2	2	2008-10-31	2010-08-18	11.41	G0V
WASP-2	1	2009-10-05	2009-10-05	11.98	KIV
WASP-3	1	2011-05-31	2011-05-31	10.64	F7V
XO-2	1	2009-02-06	2009-02-06	11.18	K0V

Table 3.2: Summary of Statistics of Known Target Data Sets

Target	Date	No. Images	FWHM (pixels)	RMS (%)	Note
HAT-P-1	2009-12-01	85	6.411	1.06	possible transit?
HAT-P-9	2009-11-03	150	10.219	9.09	large FWHM
HAT-P-13	2010-03-31	102	6.952	1.73	poor focus
HAT-P-13	2010-04-06	129	8.977	0.77	low counts; poor focus
HAT-P-13	2010-04-07	150	5.697	0.59	poor focus/guiding
HAT-P-13	2010-04-13	155	5.477	0.39	
HAT-P-13	2010-04-14	426	4.966	6.55	re-focus; left running
HAT-P-13	2010-04-18	190	7.456	40.57	low counts; poor guiding
HAT-P-13	2010-04-22	268	5.131	7.57	re-focus; left running
HAT-P-13	2010-04-26	124	7.215	1.48	poor guiding
HD80606b	2009-09-23	43	5.191	21.0	
HD80606b	2010-01-13	358	5.584	0.43	partial transit
HD80606b	2010-04-29	168	4.193	0.33	
TrES-2	2008-10-31	23	4.572	0.45	
TrES-2	2010-08-18	101	4.038	0.71	full transit
WASP-2	2009-10-05	110	6.397	4.82	
WASP-3	2011-05-31	61	5.902	0.67	
XO-2	2009-02-06	117	6.997	0.36	partial transit

4.0 HD80606b

4.1 OVERVIEW OF PLANET-STAR SYSTEM

HD80606b is one of the most unusual extrasolar planets discovered so far. It orbits the GV star HD80606 which itself is in a visual binary system, its stellar companion HD806067 located about 2000AU away from HD80606 (Naef et al., 2001) (See Figure 4.1 for a STEPUP image of the star field). HD80606b is almost four times the mass of Jupiter, and it takes 111.4 days to orbit its star¹. None of these facts are very remarkable, until you learn that HD80606b is on an orbit which takes it from 0.034AU to 0.905AU (Naef et al., 2001) with an eccentricity of 0.93366¹ and a spin-orbit misalignment of $\lambda \approx 50^\circ$ (Pont et al., 2009) ($\lambda = 0$ for a perfectly aligned system).

HD80606b was originally discovered in 2001 via radial velocity (Naef et al., 2001), and only later was it discovered that the planet transited its star. In fact the primary transit was not the first transit to be detected. Instead, in November 2007, Greg Laughlin and collaborators found a secondary eclipse in their 30-hour long Spitzer observations (Laughlin et al., 2009). A secondary eclipse occurs when a planet passes directly behind a star to our line of vision. This results in the star blocking some of the brightness of the planet. Since planets are much dimmer than stars, only a very small drop in overall brightness occurs during a secondary eclipse. So it is generally easier to see at longer wavelengths where the planet has more surface brightness relative to the star, and for planets with a higher surface temperature. Still, this is a very tiny effect, so because secondary eclipses generally have

¹<http://exoplanet.eu/planet.php?p1=HD+80606&p2=b>

such a shallow depth in the lightcurve, they are often detected *after* a primary transit has already been discovered, if they are detectable at all. However in the case of HD80606b the secondary eclipse was discovered first. The detection of a secondary eclipse was aided not only by the fact that the Spitzer observations were taken at a wavelength of $8\mu m$ but also by the fact that the geometry of the orbit is such that the secondary eclipse occurs when the planet is fairly close to periastron and reaching a surface temperature of approximately 800 K during the secondary eclipse (Laughlin et al., 2009). These two factors resulted in an observed dip of

$$\frac{\Delta F}{F_*} = 0.001 \pm 0.0002 \quad (4.1)$$

(Laughlin et al., 2009)

The existence of a secondary eclipse indicated that the system must be very close to $i = 90^\circ$ and thus increased the odds that a primary transit would occur. Based on this increased probability of transit, Greg Laughlin used his blog, <http://oklo.org>, to encourage observers across the world to look for a primary transit to occur. He predicted that the transit would last about 16 hours on the night of February 13, 2009 ², and that the odds of the transit occurring were about 15% (as compared to 11% a-priori geometric probability before the secondary eclipse had been discovered)³. Sure enough, a primary transit was discovered that night by Fossey et al. (2009).

4.2 COLLABORATIVE NATURE OF GROUND-BASED OBSERVATIONS

As the Fossey et al. (2009) paper reveals, only a partial transit could be obtained at one geographic location due to the long duration of the planetary transit. Traditionally, most transiting extrasolar planets thus observed have had a fairly short period and, as such,

²It is now known that the duration of the transit of HD80606b is actually 11.88 hours, <http://var2.astro.cz/ETD/etd.php?STARNAME=HD80606&PLANET=b>

³<http://oklo.org/2009/02/12/ready-set/>

complete a transit in no more than a few hours. This means an entire transit can easily be obtained in a single night at a single observatory. But for a longer-period planet, a transit could potentially last longer than the number of hours of darkness at any one ground-based location. Or even if the transit is not strictly longer than the number of hours of darkness, the odds of an entire transit fitting within observable nighttime hours at one particular location decrease significantly for transits whose duration is more than a few hours. For ground-based observing, then, this opens up the need for collaborative observing efforts if an entire transit is to be obtained.

This was a motivating factor behind Greg Laughlin's promoting the idea of many observers in various locations all searching for the February 2009 transit. Once a transit was discovered, this inspired a more organized collaborative effort to observe the next transit. I was fortunate enough to speak with Greg Laughlin about this opportunity when visiting the University of California, Santa Cruz in the spring of 2009. He encouraged me to contact Josh Winn at MIT and join the collaborative effort, dubbed the HD80606b Campaign⁴. Though I was unprepared to participate in the upcoming June 2009 transit (since I was just beginning my graduate studies and re-vamping my analysis procedures), I did contact Josh Winn about participating in the September 2009 transit, and the Allegheny Observatory was added to the list of observatories collaborating on the HD80606b Campaign. The collaborative effort proved successful in covering most of the June 2009 transit (Winn et al., 2009) (with just a small amount of the transit right at the beginning of the ingress not covered by the collective data), and I was eager to contribute to the goal of full coverage of the September 2009 transit. With our fledgling STEPUP team set to gather data that September 23, 2009, it unfortunately turned out to be a night of terrible weather conditions in Pittsburgh, and we were unable to obtain useable data. We were not alone in our misfortune. Indeed, the September 23, 2009 transit collaborative effort was largely unsuccessful, as only three observatories (Rosemary Hill Observatory in Florida, Fred Lawrence Whipple Observatory in Arizona, and Mount Laguna Observatory in California) were able to obtain good data

⁴<http://oklo.org/2009/09/21/campaign-mode/>

that night, and the collective data only spanned a small portion of the beginning of the transit. (Shporer et al., 2010)

Not dissuaded, the HD80606b Campaign members set our sights on the following transit, which was to take place on January 13, 2010. This time, luck would be on our side, as we joined 8 other observatories to obtain a full lightcurve of this transit event.

4.3 JANUARY 13, 2010

The observatories that contributed data to the January 13, 2010 collaborative lightcurve were the following: Wise Observatory in Israel; Gran Telescopio Canarias, La Palma, Canary Islands; Observatoire de Haute Provence, France; Allegheny Observatory, Pittsburgh, Pennsylvania, USA; Rosemary Hill Observatory, Bronson, Florida, USA; Fred Lawrence Whipple Observatory, Mt. Hopkins, Arizona, USA; Table Mountain Observatory, Wrightwood, California, USA; George R. Wallace Jr. Astrophysical Observatory, Westford, Massachusetts, USA; Faulkes Telescope North, Mt. Haleakala, Maui, Hawaii, USA. (Shporer et al., 2010) Each observatory was subject to local weather conditions and as such different amounts of data were contributed by different observatories. At Allegheny Observatory, we were fortunate to be able to contribute more hours' worth of data than any other observatory, though our most important contribution occurred during the transit egress. (Shporer et al., 2010)

Our contribution was not without painstaking struggles with some subpar data. As a team STEPUP members divided the night into shifts to decrease risk of human error due to sleep deprivation. Nevertheless, some students remained for the entire night. Others had only recently completed training on our observing procedures. Due to early morning obligations, I was only able to be present personally for the beginning few hours to help the team get set up.

When analyzing the data, it was clear that just before the egress, some of the data must not have been sensible. In troubleshooting, we were able to ascertain that some of

the problem had been due to out-of-focus data prior to a refocus that was performed about halfway through the night. Thankfully this data was salvaged by increasing the star radius in our aperture photometry from 7 pixels to 10 pixels. Other data after the refocus had actually saturated. Checking for saturation was something that had been discussed and included in the opening checklist but not emphasized as something to continually monitor.

Fortunately, most of our data was useable after the aperture radius increase was implemented and the saturated data were cut from the data set. What resulted was coverage of the transit from just after the ingress ended to after the egress was completed. No other observatory in the collaboration was able to get enough data to establish the baseline bottom of the lightcurve and include the egress and out-of-transit data as well. This made the STEPUP contribution unique in helping quantify both the transit duration and the depth of transit. In Figure 4.2 you can see each observatory’s individual data contributions. Allegheny Observatory is indicated by the label “AO.” Once the entire collaboration’s data was put together, what resulted was a very comprehensive lightcurve of the entire January 13, 2010 transit, which can be seen in Figure 4.3.

4.4 COLLABORATION ANALYSIS

Once we cut out all our un-usable data, we re-ran it through our IDL pipeline. This analysis resulted in a file containing the Julian Date and fluxes of HD80606 and HD80607 for comparison. We then generated a similar file for a night when a transit of HD80606b was not taking place.

These files were then forwarded to Josh Winn at MIT, who coordinated the collaboration. The task then remained of incorporating each set of data into the collaborative set of data points. It is difficult to combine measurements taken at different locations experiencing different weather conditions and using different instruments with different sensitivities and bandpasses. The flux ratios for each observatory must be carefully rescaled to a common

scaling. Avi Shporer at UC Santa Barbara set about doing this by assigning a normalization factor to each data set using out-of-transit data given by each observatory whenever possible (which was the case for 6 observatories). There were four observatories, however, for which there were no or negligible amounts of out-of-transit data, and, for those, the normalization factor was a free parameter in the fitting process. (Shporer et al., 2010)

For the overall lightcurve shape itself, the following Hébrard et al. (2010) parameters were adopted as constraints, since these were derived based on high-quality Spitzer data: orbital period: P , planet-to-star radius ratio: $r = R_p/R_s$, orbital semimajor axis in units of stellar radius: a/R_s , orbital eccentricity: e , inclination angle : i , and values related to the argument of periastron: $e \cos \omega$ and $e \sin \omega$ where ω is the argument of periastron. (Shporer et al., 2010)

The 8 limb-darkening coefficients were estimated and held fixed in the fitting process using grids from Claret (2004) and Claret (2000) for a star of $T_{\text{eff}} = 5645K$, $\log g = 4.5$, and $[Fe/H] = 0.43$ (Naef et al., 2001; Shporer et al., 2010).

Thus in the fitting model, there were 34 parameters. 8 of these were held fixed, 12 were controlled mainly by Gaussian priors (the Hébrard et al. (2010) parameters and the 6 normalization factors), and 14 were free parameters. These free parameters included the normalizations of the 4 observatories with insufficient out-of-transit data, and an individual periastron passage time for each observatory, which was later converted to a mid-transit time. (Shporer et al., 2010)

After an initial fit, cutting of outliers $> 4\sigma$, and weighting of each observatory's data based on the size of its errors, a final fit was performed using a Monte Carlo Markov Chain (MCMC) algorithm (Shporer et al., 2010). The end result for the January 2010 transit had $\chi^2/N_{\text{dof}} = 442/429$ (Shporer et al., 2010). This fit is overplotted with the data points in Figure 4.2 and Figure 4.3.

4.5 RESULTS OF COLLABORATIVE EFFORT AND STEPUP CONTRIBUTION

The collaboration analysis resulted in 10 mid-transit time estimates, one for each observatory. Of these 10 estimates, 3 had large uncertainties, and these corresponded to observatories with less than 5 hours of transit data, and no out-of-transit data. These were eliminated before averaging the remaining 7 to determine a collaborative mid-transit time estimate. (Shporer et al., 2010) The average was unweighted in order to average out possible correlated noise in the individual estimates. If a weighted average is used, the mid-transit time changes by $< 0.25\sigma$. The unweighted average yields an HJD mid-transit time of $T_c = 2455210.6502$ with an rms uncertainty of 0.0064 days (Shporer et al., 2010). This mid-transit time is in between the mid-transit time derived from the Hébrard et al. (2010) Spitzer observations, and the mid-transit time predicted by Winn et al. (2009). Specifically, this mid-transit time is 1.3σ later than the Hébrard et al. (2010) mid-transit time, and 1.1σ earlier than the Winn et al. (2009) predicted mid-transit time, which does not confirm or refute the Hébrard et al. (2010) result (Shporer et al., 2010). Thanks to our ability to get many hours' worth of data (including out-of-transit data) STEPUP was one of the 7 contributors to this estimate of the collaborative mid-transit time.

One other aspect of the Hébrard et al. (2010) Spitzer observations that was neither confirmed nor refuted by the ground-based collaboration was the “bump” in the Spitzer lightcurve. This “bump” amounted to an hour-long increase in flux of $\sim 0.1\%$ just before the mid-transit which could be explained by the possible presence of a star spot (Hébrard et al., 2010). The ground-based effort did not have the sensitivity to identify such a small flux variation; however, the collaboration data implies that it is unlikely that there was a flux increase of 0.2% (Shporer et al., 2010). The STEPUP data included the time period during which the Spitzer “bump” was observed and as such helped constrain the size of the possible flux increase as likely being $< 0.2\%$.

Considering the amount of data STEPUP obtained, and the advantageous timeframe

during which our data contributions took place, we were able to contribute in a useful way to a collaborative ground-based effort to observe a transit of HD80606b. This effort has served to show that complete and accurate lightcurves can be obtained for longer-period planets by working together from the ground. Such efforts will no doubt become an affordable way to complement space-based observations as more longer-period planets are discovered.

For example, if we want to follow-up on any planets discovered in the habitable zone of a Sun-like star, this would involve a long transit duration. Consider the Earth orbiting the Sun. The duration of the Earth transiting the Sun can be calculated by considering the portion of Earth’s orbit during which the Earth would be transiting to a distant observer. The geometry would look very similar to that in Figure 1.2, only imagining that instead of the orbital plane being perpendicular to the page, it is parallel to the page. In that case, the transit duration will last from the time the planet is in the position depicted until the planet is 2θ from where it is currently depicted. For clarity, we can call that angle α , and, using the small angle approximation again, $\alpha \approx \frac{2(R_* + R_p)}{a}$. For the case of the Earth and the Sun, $R_{\text{sun}} \gg R_{\text{earth}}$, so we can approximate this as $\alpha \approx \frac{2R_{\text{sun}}}{a}$. This is the angular portion of the Earth’s orbit during which the transit takes place, so the fraction of this angular portion to the whole orbit would simply be $\frac{\alpha}{2\pi}$. To determine what this fraction of the orbit is in time, we need only multiply by the period of the orbit: in this case, one year. Plugging in 1AU for a and the radius of the Sun for R_{sun} , we find this transit duration to be ~ 13 hours, very similar to that of HD80606b. This means that potentially-habitable worlds will likely require collaborative observing efforts like the HD80606b Campaign, for ground-based follow-up to capture an entire transit.



Figure 4.1: Image from STEPUP data of HD80606 starfield. The visual binary system of HD80606 and HD80607 is clearly visible near the upper part of the image. HD80607 is the left of the two stars and HD80606 is the right of the two stars.

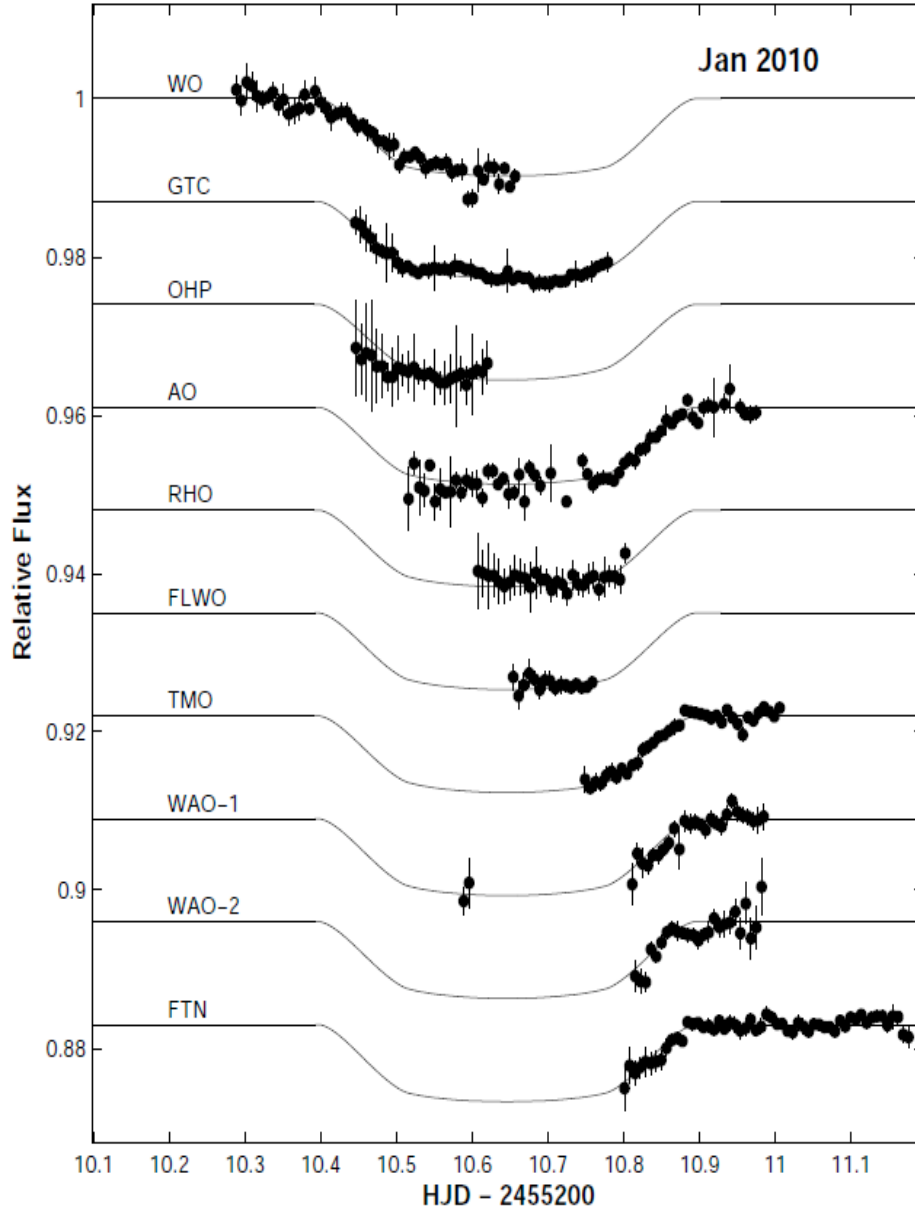


Figure 4.2: (Shporer et al., 2010, Fig. 1), Individual HD80606b transit data from 10 observatories with best-fitting model overplotted. Allegheny Observatory is indicated as AO. Note that the lightcurves are separated by an arbitrary vertical offset so that they can be seen individually.

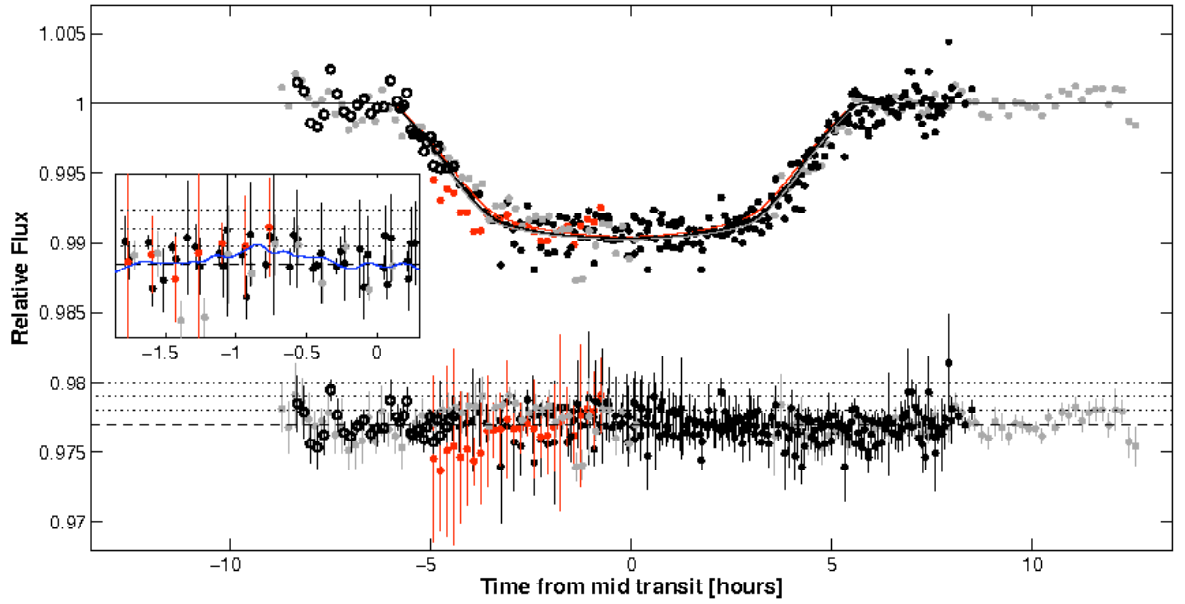


Figure 4.3: (Shporer et al., 2010, Fig. 2), HD80606 Collaborative Lightcurve. Z-band data are in gray, i and I data in black and r data in red. September 2009 data are indicated by open circles; whereas, filled circles are the January 2010 data. Plotted below the lightcurve are the residuals, with error bars. The inset shows a zoomed-in view of the residuals when a “rebrightening” or “bump” was observed with Spitzer, a feature which is overplotted in blue Hébrard et al. (2010). The collaboration data neither confirm nor refute the existence of the bump Shporer et al. (2010).

5.0 SDSS-III MARVELS

5.1 MARVELS PROJECT DESCRIPTION

The Multi-object APO Radial-Velocity Exoplanet Large-Area Survey (MARVELS) is part of the Sloan Digital Sky Survey-III. MARVELS simultaneously observes multiple targets, which it achieves by using a multi-fiber instrument that combines a spectrograph with a Michelson-type interferometer. The advantage of measuring multiple objects at once is that it is more efficient in discovering many planets than single-object surveys; thus this technique more quickly amasses a large sample. MARVELS will monitor 8,400 stars in total ([Eisenstein et al., 2011](#)), most of which are main sequence stars in spectral classes F, G and K and a small portion of which are giant stars for roughly 5 years. The magnitude of the stars being monitored is $8 < V < 12$. By monitoring stars that meet these criteria, MARVELS targets will be a well-controlled sample, and, having large amounts of data gathered by the same instrument, any systematics will be consistent across the sample. The main goal is to provide a large, statistically significant, controlled sample of gas giant planets of $M > 0.2M_J$ that can be used for testing detailed models of planet formation, migration and dynamical evolution. It is expected that MARVELS will detect between 150 and 200 planets around main sequence stars. Of those planets that MARVELS finds, it is expected that about 10 of them should be transiting systems, which is more than double the number of transiting systems found in previous radial velocity surveys ([Eisenstein et al., 2011](#); [Ge and Eisenstein, 2009](#)).¹

¹<http://www.sdss3.org/collaboration/description.pdf>

5.2 PHOTOMETRIC FOLLOW-UP OF PLANETARY CANDIDATES

Once a periodic RV signal is found on a particular MARVELS target, photometric follow-up of this individual star can be undertaken. Identity, coordinates and other pertinent information is only shared with MARVELS collaborators; this is where STEPUP enters the picture. Through our collaborative relationship with MARVELS, we are given proprietary information on the target star. That information includes such things as the coordinates of the star, its magnitude, and an image of the star field. This allows us to find the star and observe it for any possible signs of transit.

More specifically, the STEPUP team chooses the specific MARVELS target(s) to monitor based on the observability of the target at a particular time of year. Then this target takes priority and on any clear night we take a continuous set of images of the target throughout the night, choosing the exposure time based on the flux we receive from the star (see Section 2.3.1). Since MARVELS targets tend to host massive sub-stellar companions on short periods of a few days or less, this observational strategy gives us some assurance that over several weeks' time, we ought to have a good chance of stumbling upon a transit should the system be aligned close to $i = 90^\circ$.

On the other hand, observing constant flux is also important information because it can contribute towards ruling out a transiting geometry. This would imply that the mass estimate $M_p \approx M_p \sin i$ is only a lower limit for the true mass of the orbiting object. Thus far, none of our observed MARVELS targets have exhibited any inconsistency with a constant flux which might indicate a possible transit.

Given the expected yield of transiting planets and our photometric sensitivity, we can determine what size planets we are capable of detecting should they transit and see how well that aligns with the expected types of planets MARVELS should discover. Since MARVELS expects to detect massive planets of $M > 0.2M_J$ and since extrasolar planets are often found to have radii at least as large, if not larger than theoretical predictions (Laughlin et al., 2005; Kuchner and Seager, 2007), it is reasonable to expect the planets MARVELS discovers to be

$R \geq 0.5R_J$ (Kuchner and Seager, 2007). Table 5.1 summarizes what size planet STEPUP is sensitive to for a give magnitude (listed in the first column). The second column lists typical RMS values from STEPUP data taken during optimal conditions. The third column gives what the square of the planet-to-stellar radius ratio would be that corresponds to a 3σ detection, given our typical RMS. The final two columns give a size of planet that this implies would be detectable for a star twice the size of the sun and a solar-sized star. These two values were chosen as examples, since MARVELS is not targeting very many stars more massive than spectral class F, and for stars smaller than the sun, the size of planet STEPUP can detect is $\sim 0.2R_J$ which is even smaller than the typical size planets MARVELS is expected to discover. Indeed this size planet corresponds to an object with $R_p \sim 2.24R_{\text{earth}}$.

Even for a solar-sized star of 10th magnitude, STEPUP can detect a planet of $R_p \sim 0.34R_J \approx 3.8R_{\text{earth}}$, which is still well below the Jupiter-sized objects MARVELS expects to find. This means that STEPUP is sensitive to planets MARVELS is not. This gives STEPUP a unique parameter space to explore and enhances our likelihood of discovering a new transiting planet. In particular, since the MARVELS targets given to us are already suspected to host substellar companions, these stars are more likely to host other, smaller companions that could be detectable by STEPUP. This provides a more focussed search than simply observing a random sample of stars which may or may not host planetary companions. For example if half the stars that host one planet also host more than one planet, there is a roughly 50% chance that one of the MARVELS targets might host additional orbiting objects.

Furthermore, if a transit of a MARVELS candidate is discovered, then any additional orbiting bodies have an increased probability to also transit. If we assume relatively small inclinations of the orbital planes of the orbiting objects (a reasonable assumption based on planetary formation models), then if one of them transits, another almost always will (Borucki et al., 1996). Even for larger inclinations of the orbital plane (an angle we will call ϕ), there is still a greater likelihood that the additional object will transit. According to Borucki et al. (1996) (Eq. 2), for $\phi \geq \frac{2R_*}{a}$ the probability that a second planet will transit,

Table 5.1: Size of Planets Detectable to STEPUP

Mag	RMS	R_p^2/R_*^2 for 3σ detection	R_p for $R_* = R_{\text{sun}}$	R_p for $R_* = 2R_{\text{sun}}$
10	0.39%	0.0012	$0.34R_J$	$0.68R_J$
11	0.71%	0.0021	$0.46R_J$	$0.92R_J$

given that the first planet transits is given by:

$$P_2 = \frac{1}{\pi} \arcsin \frac{\sin(2R_*/a)}{\sin \phi} \quad (5.1)$$

According to this equation, then, even if the second planet was inclined as much as 7° to the first (as is the case with Mercury, the planet exhibiting the largest inclination in our solar system to the ecliptic), a planet orbiting a Sun-sized star at 1AU would have a $\sim 2.4\%$ probability to transit, which is much higher than the $\sim 0.3\%$ transit probability of the Earth around a Sun-sized star, as derived in Section 2.3.2 using Equation 1.1. Although a planet as small as the Earth is not detectable by STEPUP, the use of Equation 1.1 for a planet which could be detected (eg. $R_p \approx 3.8R_{\text{earth}}$ as mentioned above), would yield a very similar transit probability to that of Earth (assuming $a = 1\text{AU}$), since it would still be true that $R_{\text{sun}} + R_p \approx R_{\text{sun}}$. Thus we enhance our likelihood of discovering additional, smaller objects by selecting MARVELS candidates over stars not yet known to host any substellar companions, and this enhancement is even greater if the MARVELS candidate is found to transit.

5.3 ANALYSIS OF MARVELS TARGETS

5.3.1 Problems Encountered

The first MARVELS target we observed was located in a very dark portion of the sky, and finding a suitable tracking star proved to be a challenge. What resulted in terms of raw data were sets of images with the target near the edge of the field of view, some images in which the stars were badly streaked. Moreover, in an attempt to expose the target long enough, some data sets had exposure times that saturated some of the other, potential reference, stars in the images. This made analysis of the Fall 2010 semester of data difficult.

Some other problems encountered were the discovery that refocussing during an observing run does not seem to affect all stars' psf the same way, especially when they appear far from the center of the field of view. Upon analyzing such data sets, trends appear in the data just at the time(s) of re-focus. For examples of this, see Figures [D21](#), [D23](#), and [D49](#) in Appendix [D](#).

Finally there were a couple evenings in which star flux was lost through the night, sometimes disappearing altogether by the end of a data set. This would sometimes happen when the telescope was left to run after active observers had left for the night. The resultant lightcurves seem to exhibit an “ingress” just as flux was being lost. It is more likely that this “ingress” is related to this loss of flux than to a true planetary transit ingress. For examples of this, see Figures [D27](#) and [D43](#) in Appendix [D](#).

5.3.2 Troubleshooting and Re-Analysis

Starting in January 2010, careful troubleshooting was undertaken to uncover and correct some of the problems mentioned above, such as cutting some data, and using different reference stars if they were saturated in some data sets. Re-analysis proved largely successful in salvaging most data sets, and we can say with greater confidence that no signs of transits have yet been discovered in our observations of MARVELS targets.

For an example of this sort of null finding, see Figure 5.1. This particular example was well-studied by STEPUP from the months of May 2010 through September 2010. In addition to visually seeing from examples such as this that the flux appears to remain constant, our data was also compiled over this four month interval and run through a software package called Transit Analysis Package, TAP (Gazak et al., 2011)², to search for signs of a transit. This software package was designed at the University of Hawaii and is publicly downloadable. TAP takes the analytic model presented in the seminal Mandel and Agol paper on analytic light curve parameters (Mandel and Agol, 2002) and uses Markov Chain Monte Carlo (MCMC) techniques to fit lightcurves using this model, in the process parameterizing correlated and uncorrelated noise (Carter and Winn, 2009; Eastman et al., 2011). Using TAP no correlated variation in flux was found for the predicted period. However, this does not yet rule out the possibility that this planet could transit, since this particular example has a somewhat longer expected orbit of roughly 50 days. So despite our extensive observations, our data still only cover a fraction of the entire orbit. Nevertheless our findings contribute towards further understanding this planetary candidate.

For more examples of findings consistent with a constant transit, see Appendix D for a compilation of STEPUP lightcurves of MARVELS targets.

5.4 CONCLUSIONS

As mentioned in Section 3.1, the STEPUP photometric findings for MC002 will be used in an upcoming paper about this particular target. Our findings thus far are consistent with a constant flux and show no signs of a transit. However, with such a long period planetary candidate, the possibility of transit is not ruled out. Since STEPUP involvement with MARVELS is relatively recent, further observations of MC002 and/or other MARVELS targets may continue to be consistent with constant flux or may reveal signs of a transit.

²<http://ifa.hawaii.edu/users/zgazak/IfA/TAP.html>

Thus STEPUP will continue to observe MARVELS targets to search for signs of transits. A summary of the MARVELS targets observed, dates and number of data sets can be found in table 5.2. STEPUP is sensitive to detecting planets as small as $\sim 0.4R_J$ for a 10th-11th magnitude solar size star which is around the minimal size planets MARVELS is expected to discover. For stars twice as large as the sun, STEPUP is sensitive to planets between $\sim 0.8R_J$ and $\sim 0.9R_J$ for a 10th-11th magnitude star. Finding a transit from a MARVELS target will help confirm the size and planetary nature of the candidate, and STEPUP will thus contribute important information to the process of planetary discovery.

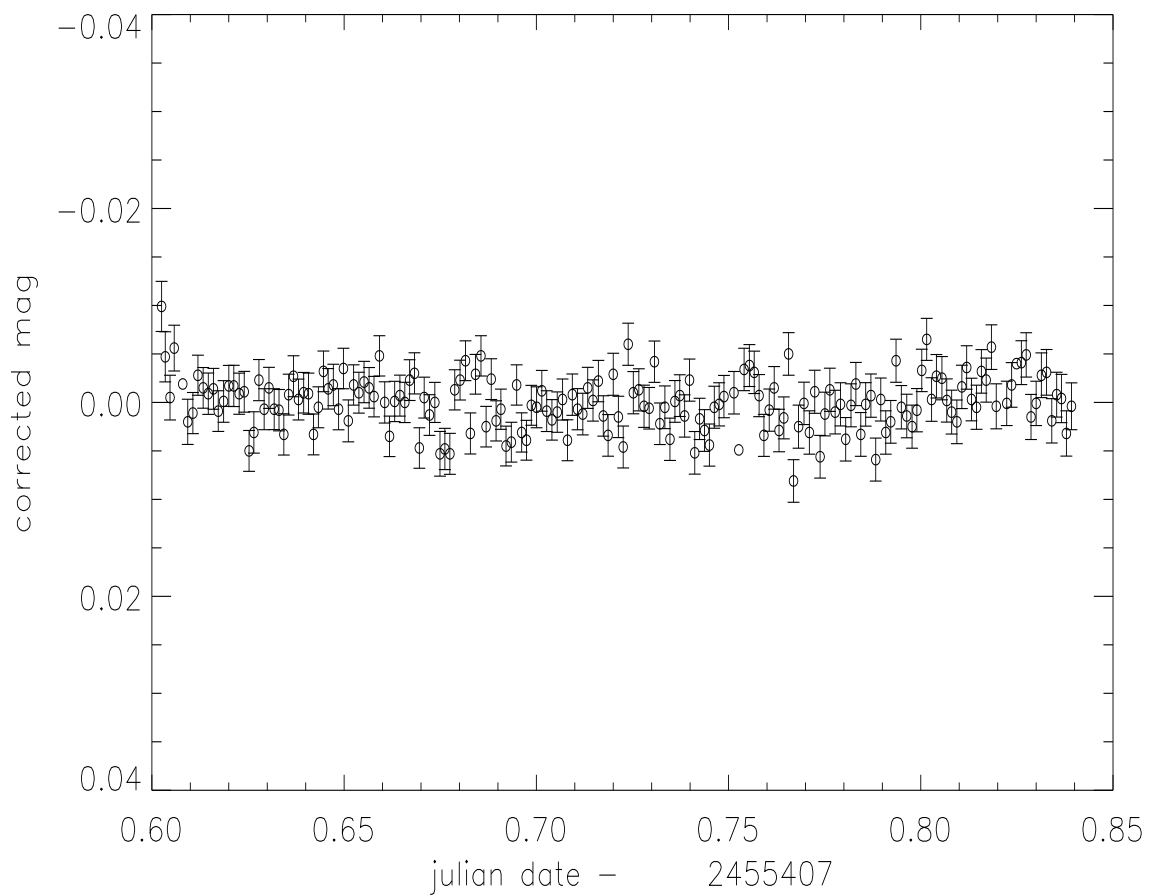


Figure 5.1: Photometry of a MARVELS Target from July 29, 2010

Table 5.2: Summary of MARVELS Targets Observed

Target	Number of Data Sets	Beginning	Ending
MC000	1	2010-03-04	2010-03-04
MC001	6	2011-02-03	2011-03-02
MC002	21	2010-05-25	2011-06-30
MC004	1	2010-11-09	2010-11-09
MC006	9	2011-02-03	2011-03-27
MC007	5	2011-04-05	2011-05-11
MC009	7	2010-05-03	2010-05-27
MC010	4	2011-02-23	2011-03-19
MC024	6	2011-04-05	2011-06-01

6.0 FUTURE DIRECTIONS AND CONCLUSIONS

6.1 FUTURE DIRECTIONS

6.1.1 Hardware Improvements

As of the beginning of January 2010, it was possible to securely log into the Allegheny Observatory Keeler computer from elsewhere. With this ability, one can operate the telescope, move the dome, switch the lights inside the dome on or off, take images, etc. This gave STEPUP the freedom to observe from Allen Hall on campus without the need for independent transportation to the Allegheny Observatory. This freedom was a huge boon for the undergraduate researchers who often did not have access to their own vehicles.

Even with this freedom, however, we have had to coordinate observation runs with Lou Coban at the observatory, since we have no way of removing or replacing the telescope cover. In the summer 2011, Kaitlyn Yoha, a student from the School of Engineering is designing and building a telescope cover for the 16" Keeler that can be operated remotely. This project will complete the process of making the Keeler fully remotely operable. This final piece of the puzzle should be complete by the end of August 2011 with the implementation of the remotely-operable Keeler cover. Once this improvement is in place, STEPUP members will be able to remotely observe at any time, even if no one is physically present at the observatory.

Additional recent and ongoing hardware improvements involve the upgrading of the Thaw telescope. The Thaw is an historic telescope. It was built in 1912 with a 30" lens, making

it the third largest refracting telescope in the country.¹ The Thaw is fitted with a Finger Lakes Instruments FLI-4240 CCD camera. The chip on the camera is a thinned backside illuminated CCD chip with a 2048 x 2048 array of 13.5 micron pixels. Unfortunately the telescope wiring which had historically been advantageous in the past severely constrained the use of the Thaw for extrasolar planet transit observations, as it fed the wiring through an external bridge that limited the mobility of the Thaw and restricted it to the western side of the pier.

Thus, STEPUP members Gary Lander and Korena Costello have, over the past two years, made improvements to the Thaw telescope to get it ready for future use with STEPUP research. The first project was to re-wire the Thaw to give it full mobility to slew wherever we wanted it to. This was a long and tedious process, but was completed by the winter of 2011. On February 11, 2011, the success of the re-wiring was tested when the telescope was moved to the eastern side of the pier for the first time in roughly 40 years.

In addition new software was installed and the CCD camera is currently set to be repaired. Also, the RA and Dec limit switches are being revamped. By the end of 2011, STEPUP hopes to be able to use the Thaw telescope for extrasolar planet research in addition to the 16" telescope. A detailed account of all the work done on the Thaw by STEPUP can be found in a write-up by undergraduate member Gary Lander. From any of the astro computers the file can be found here:

`/home/giga/ugrads/gr15/Thaw_Writeup/Thaw_Writeup.pdf`

6.1.2 Analysis/Pipeline Improvements

Some STEPUP members are working on a way of stacking our images to find asteroids whose position could be used to calibrate the timing of data sets taken at different locations. This project is useful for any collaborative observing effort such as the HD80606b Campaign, since it will allow the relative timing of data sets from different locations to be known with respect

¹<http://www.pitt.edu/~aobsvtry/index.html>

to any asteroids that are also in the field of view. This sort of analysis is being developed in a separate pipeline:

```
/home/depot/STEPUP/code/asteroids
```

The most ambitious improvement to the STEPUP pipeline is also underway. STEPUP member Justine Drobitch is undertaking the task of improving our photometry by performing relative photometric measurements of every star in the field of view and calculating the relative photometry of the target compared to all other stars. This requires a more efficient way of storing the measured brightnesses than in a columned data file. Most of the new code for this improvement has been written and is in the process of being tested. The hope is that this approach will ultimately decrease our errors.

6.1.3 Additional Projects

In addition to the analysis improvements using photometry on all stars, future analysis goals will be to continue developing a more sophisticated fitting algorithm, to find a better way to optimize the aperture radii chosen for each target, and to explore and understand better the source of our errors.

Finally, in terms of hardware improvements, the work on the Thaw telescope is likely to be an ongoing effort through the end of 2011. As mentioned above, things that still need to be upgraded include replacing the camera, being sure the RA and Dec limit switches are working properly, and troubleshooting any bugs that are encountered as the Thaw is tested for use as an active observing telescope.

6.2 SUMMARY OF STEPUP WORK

The Survey of Transiting Extrasolar Planets at the University of Pittsburgh has been a project which has conducted follow-up observations of unconfirmed substellar companions

as well as of known planets. To these ends, STEPUP has contributed in an important way to a new collaborative approach to ground-based observations of HD80606b. This collaborative effort has demonstrated the success of coordinating observations across geographical distances in order to achieve full coverage of a long planetary transit. This lays the groundwork for future follow-up collaborative efforts as more long-period transiting planets are anticipated to be discovered. In addition, STEPUP has submitted interesting follow-up data to public scientific entities, such as the Exoplanet Transit Database (Poddaný et al., 2010). In particular, STEPUP data for observations of known planets such as TrES-2b may be of use to astronomers looking to explore the possibility of transit timing variation and/or transit duration variation. Finally, STEPUP has provided photometric observations for the SDSS-III MARVELS planetary candidates. This photometric information is helpful in the planetary confirmation process. Moreover, if a transit is discovered for a MARVELS candidate, STEPUP will have helped determine crucial parameters of the candidate, such as a reliable mass and radius, from which other characteristics can be derived.

All of these efforts have contributed to scientific understanding of extrasolar planets. With the pace of planetary discovery rapidly increasing, follow-up observations will become increasingly more crucial. Hence, small observatory follow-up contributions to larger scientific collaborations are a thorough and cost-effective way of increasing knowledge of extrasolar planets. (Seagroves et al., 2003) The current era in extrasolar planetary science is one in which we are building up empirical information and in the process, we are uncovering startlingly unique worlds. Understanding the nature of the plethora of planets that exist requires not only discovering them, but also carefully studying them in more detail. And through the information we gain in such careful follow-up study, we shed light on the nature of planetary formation, migration, and other such theoretical matters.

In conclusion, providing useful observational study of extrasolar planets and planetary candidates will continue to be the goal of STEPUP. These observational efforts are not done in isolation but connect intimately to the greater scientific community and help to develop collaborative efforts to understand the diversity of worlds in the cosmos.

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APPENDIX A

HOW TO PLAN OBSERVING

Below is the STEPUP detailed strategy for planning observing of known extrasolar planets.

How To Plan Known Transit Observations

Melanie Good

2011 May

1. Strategy

One of the STEPUP objectives is to gather follow-up data on known planetary systems. We can strategically plan our observing in order to meet this objective by using some online resources. For planets that are known to transit, the recommended website is called Exoplanet Transit Database. For planets that were discovered by other techniques and are not yet known to transit, the recommended website is called Transitsearch. Each of these two sites has its advantages and disadvantages which makes them more useful for the particular application of either known or unknown transiting systems. Either way, the general strategy you want to follow is this:

1. Choose a target then plan a night to observe or alternatively, choose the night you can observe and find the best target for that night. Considerations for choice of target:

- a. Since one of our other objectives is to get images that might also contain asteroids, try to choose a target of low ecliptic coordinates. You will likely have to convert Ra and Dec to ecliptic coordinates using `skycalc`.

- b. Try to find a transit that is predicted to have a transit depth of at least 0.5%

- c. The duration of the transit should easily fit within your observing timeframe.

2. Use the website recommended to plan when that night to observe. You want to get some data both before the transit begins and after the transit ends.

3. Obtain an image of the star field with the target marked so that you can identify it when you observe and keep it as close to the center of the field of view as possible. Many of these should be in the binder in Allen 416 along with any notes about tracking stars that have been used in the past. If not, star field images are automatically available on Exoplanet Transit Database or can be found using `Simbad`. If STEPUP has not previously observed the target, you might be also able to pick out a few stars that could serve as a tracking star if you find an image of roughly the same size as our field of view. If you are unable to find a tracking star before observing, be sure to take careful note of the tracking star in your observing report so that it can be used for future observations.

2. Exoplanet Transit Database for Known Transiting Planets

Here are the basic steps to follow to use Exoplanet Transit Database (ETD):

1. Go to <http://var2.astro.cz/ETD/>
2. Click on “Transit Predictions” near top
3. Input our latitude and longitude. Note that it is *East* Longitude!! For our purposes, it’s good enough to input 280 degrees ELongitude and 40 degrees Latitude. Press the “submit” button.
4. You will see a chart of predicted transits, along with the duration of the transit, magnitude of the target star, depth of magnitude, and coordinates. Above that are several upcoming dates you can click on to change the chart to a different night’s predictions so you can plan your next observing night accordingly. “Begin” is approximately when you can expect the transit to start. “center” is the approximate mid-transit time, and “end” should be when the transit is done. Times are in UT, which for summer is 4 hours later than our local time. After we set our clocks back in the fall this will become 5 hours later than our local time. So to find the mid-transit time in local time, subtract the appropriate number of hours from the time listed in these columns.
5. Once you choose your target (keeping in mind our strategy for target choices), you can click on the object name and you will see an image of what the star field looks like and which star is the target. Below that is a year’s worth of predicted transits, complete with colors to indicate observability at our location. Grey times indicate the star is not rising above 20 degrees above the horizon, yellow times indicate the transit is taking place during the day, and black times indicate the star is above 20 degrees and the transit takes place at night in our location. This is helpful in planning future observations.

3. Planets Not Yet Known To Transit with Transitsearch

Following up on planets not yet known to transit is a secondary objective. Should you choose such observations, the planning process is less user-friendly. Transitsearch used to have a similar functionality to ETD where you would input your local latitude and longitude and it would give you some predictions. However, it now only consists of charts that you must wade through to plan your observing, and there are a few bugs that remain with it. This should not dissuade you because Transitsearch is still a useful tool if you want to prioritize which targets to look for a transit for based on their probability of transiting (which is included in the charts).

Here are the basic steps to follow to use Transitsearch:

1. Go to <http://www.transitsearch.org/>
2. Click on “Candidates” to make an interactive table appear
3. Understand each column to help plan which target to observe when:

-First three columns are pretty self-explanatory; they identify the target by name and tell you its orbital period

-Fourth column tells you the probability that the planet transits. 100% means it is a known transiting planet. Other percentages are based on the geometric probability that a system that has not yet been shown to transit actually does transit.

-Columns five and six give you the coordinates of the target

-Column seven tells you the depth the transit ought to have (as a percentage). We know we can detect a 1% transit depth and possibly a little less but if this number is less than 0.5%, it’s unlikely we could detect it.

-Column eight tells you the predicted mid-transit time for the soonest transit from now. This time is in UT, which for now is 4 hours later than our local time. After we set our clocks back in the fall this will become 5 hours later than our local time. So to find the mid-transit time in local time, subtract the appropriate number of hours from the time listed in this column.

-Column nine tells you if the transit is taking place during the day or night. “In” means it is taking place at night; “out” means it is taking place during the day. But be careful because I have found marginal cases that would actually be observable even though they are labeled “out,” as I think these designations are based on the west coast (since Greg Laughlin, who maintains the site, is located at UC Santa Cruz). So don’t rule out a possible target just based on this column—take a more careful look at column eight.

-The tenth column is probably one of the most useful columns. By clicking on this column you will be given a detailed chart of the timing of each transit (ie. an “ephemeris”) from about a year ago to about a year from now. In addition to HJD the dates and times are listed, again all in UT so you must subtract hours if you want to know them in local time. The “begin transit window” is approximately when you can expect the transit to start. “Predicted central transit” is the approximate mid-transit time, and “end transit window” should be when the transit is done. Ideally you’d like to get some data before the beginning of the transit and after the end of it. The transit duration is listed at the top. Also be careful with these ephemeris pages. I have recently clicked on a few where, instead

of the times following the three columns they should, it appears that the left-hand column starts at one date chronologically until it fills that column and then the second column is a continuation of the bottom of the first column. Instead of telling you the whole transit window, all you are given is the mid-transit time for that particular date. If you encounter one of these faulty ephemeris pages, you can get a rough idea of when the beginning of the transit is by looking at the transit duration and assuming that subtracting half the total duration off the mid-transit time ought to give you the beginning of the transit, and adding half the total duration to the mid-transit time should give you the end of the transit window. Please email the list when you encounter such pages, as we may want to alert Greg Laughlin of these bugs.

4. Once you are familiar with these columns you can see that you can use them to either look for a particular night you are observing and see what might be a good target, or choose a target and then look for the next predicted transiting evening, and plan your future observing accordingly.

APPENDIX B

APERTURE RADII CHOSEN

Below is the write-up detailing our choice of aperture radii used in the `aper` command of our photometry module.

Aperture Radii Chosen for *aper* in *gtphluxometry.pro* Module

Melanie Good

2011 May

1. History of Radii Used in *aper*

From the early days of our analysis, aperture photometry was performed using the *aper* command in IDL. The radii were chosen to suit our only set of data at that time, XO-2/2009-02-06. Originally they were set to be 7 pixels for the star radius, and [15,20] for the inner and outer sky radii. This gave us reasonable results for this original set of data. It is worth noting that, using these radii, the ingress for this particular transit was quite clear in the original analysis without the use of any astrometric tweaking with the *gcntnd* command. Once the *gcntnd* command was implemented in the photometry, this gave even better results with a smaller standard deviation. Based on the success of this particular analysis, *gcntnd* was thereafter used in the photometry module, and the radii in *aper* were set to the values listed above, so that we had the following sequence of commands after reading in the reference catalog:

```
ad2xy, ra, dec, astr, x, y
gcntnd imagw, x, y, xcen, ycen, 5
aper, imagw, xcen, ycen, mag, errap, sky, skyerr, 1.48, [7], [15,20], [0,0], /NAN
```

During the HD80606b campaign in January, 2010, it was decided that a bigger star aperture would give us better results after our initial analysis attempts revealed some out-of-focus data. (There were other problems with our data, such as some saturated data that had to be cut, but that was a separate issue). The change to a 10-pixel star radius was implemented and gave us good results for our HD80606b/2010-01-13 data that ultimately earned STEPUP our first published work.

For unclear reasons (likely due to simply forgetting that this change to a larger star radius had been made), the 10-pixel star radius remained in the *aper* command for over a year until other troubleshooting efforts in teasing out the best results we could from our MC002 data revealed that the star radius in the *aper* command was never changed back to 7 pixels.

2. Calculating Optimal Signal-to-Noise

In April, 2011, an effort was made to calculate what star radius would yield optimal signal-to-noise for most of our data sets. This was done both to quantitatively justify our choice and to investigate whether we would do better to revert to the smaller radius used in the past. The following email was sent to the group 2011-04-22 at 12:28:44 PM EDT summarizing the results of this investigation:

“I have added the signal-to-noise calculation to

“/home/depot/STEPUP/code/TransitErrors/radwatv.pro

“and had it print out the S/N for various aper radii. I then ran this module on two different nights of data.

“The first was a night of poor seeing: 2011-03-02/MC001 where the seeing in the observing report was listed as 1/5 and FWHM was 4.45 pixels. The resultant output file I generated is /home/depot/STEPUP/code/TransitErrors/signaltonoise.txt You will see that the S/N is best at 8 pixels for this night; however this is only $\tilde{2}$ % better S/N than the S/N for the radius the code currently has aper set at (10 pixels).

“The second night of data was decent seeing: 2010-08-18/TrES-2 where the seeing in the observing report was listed as 3/5 and FWHM was 2.98 pixels. The resultant output file is /home/depot/STEPUP/code/TransitErrors/signaltonoise2.txt Comparing this to the first night I ran, we see that the S/N is best at 5 pixels for this night, AND this is a significant improvement over the 10 pixels radius: we get $\tilde{15}$ % better S/N by decreasing the radius to 5 pixels.

“My conclusions are the following:

“1. Even for poor seeing nights, 10 pixels does not appear to be the optimal radius. Certain weird circumstances might cause us to go this big (like the HD80606b campaign) but I don’t think it’s warranted in the vast majority of cases.

“2. That said, changing it from 10 pixels to a smaller radius may not make that big of a difference for poor seeing nights, but might make a big difference for nights of good seeing. Thus it might be worth including this S/N calculation near the beginning of generaltransit to calculate the best radius to use and then feeding this optimized radius to aper.”

Based on these results, the star radius in the *aper* command was restored to 7 pixels.

3. TrES-2 Re-Analysis

With the implementation of this change back to a 7 pixel star radius, TrES-2/2010-08-18, our useful test case of a clear and complete transit, was re-analyzed on 2011-05-03 using this radius.

Unfortunately, though the individual errors appeared smaller in the .dat output file, the overall spread was *worse*, not better, than before. See Figure 1 and Figure 2 for a visual comparison of the lightcurves that resulted.

At first it was unclear if it was only the aperture radius change that resulted in this much poorer lightcurve, but a quick re-analysis with the aperture radius changed back to 10 pixels reproduced the original, better lightcurve. Due to TrES-2 giving us obviously better results with at 10-pixel star radius, the star radius in the *aper* command was changed back to 10 pixels on 2011-05-19.

The exact reason for the better results with a 10 pixel radius is not entirely clear, since the calculated signal-to-noise is much better with a smaller radius, and this is also shown by the individual errors improving with a smaller radius. Thus reason likely has something to do with the image-to-image variation using this smaller radius, and this leads to the possibility that perhaps imperfect astrometry is to blame. If this is the case, then it could be that with a smaller star aperture, some of the light of the star is being cut off in some images that are not as well-centered as others. Further investigation is warranted.

On 2011-05-20 the sky annulus was changed from [15,20] to [15,35] to help us better characterize the background noise above which we are attempting to measure the stellar brightness. TrES-2/2010-08-18 was then re-run again and found to have less of a photometric spread in the lightcurve. See Figure 3. A more careful investigation of the optimal sky annulus is also warranted.

4. Future Investigations

As mentioned above, it will be important in the future to get to the root of the problem with a smaller radius. In the meantime STEPUP may have to accept the larger individual errors in favor of a larger radius to yield better overall results. However, this underscores the fact that there is certainly room for improvement. If astrometry is revealed to be the issue, then if we can do a better astrometric job of centering our apertures, then we can use a smaller star radius that would be closer to our optimal signal-to-noise and thus obtain better results.

In addition, the sky annulus needs to be optimized. At the time of this writing, it is under loose investigation and will be increased to see if better results can be obtained, but a systematic and thorough investigation of this would be an important near-term goal. Better characterization of our sky will allow us to better characterize how bright our stars are in comparison to the background noise, which will in turn give us better photometric measurements.

5. Conclusions

At the present time the *aper* command looks like this:

```
aper, imagw, xcen, ycen, mag, errap, sky, skyerr, 1.48, [10], [15, 35], [0,saturation], /FLUX
```

It is recommended that the star radius of 10 pixels remain as is until such time as it can be shown what the reason is for such a large radius giving us better results, and that reason can be addressed. In addition, further investigation of the optimal sky annulus is also recommended.

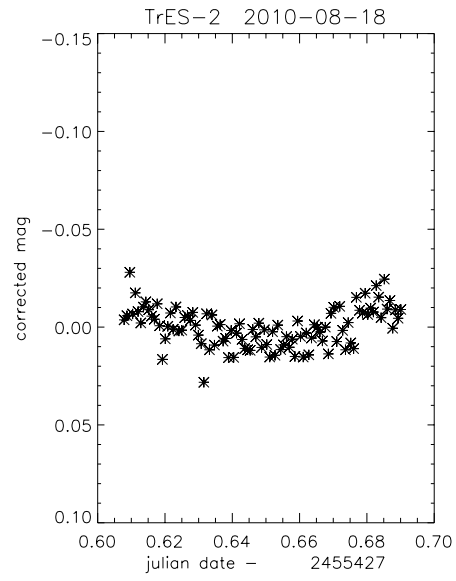


Fig. 1.— TrES-2/2010-08-18 Lightcurve with a 10-Pixel Star Radius

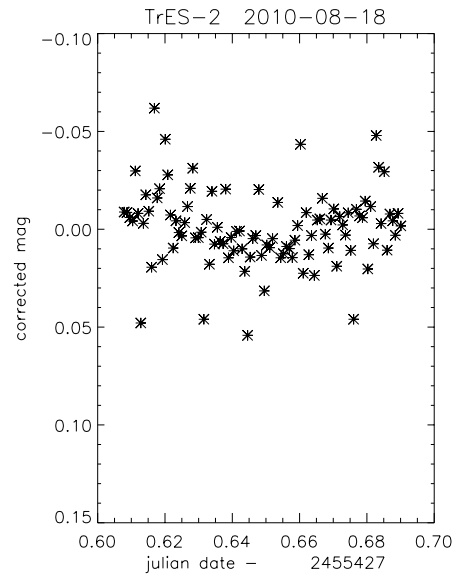


Fig. 2.— TrES-2/2010-08-18 Lightcurve with a 7-Pixel Star Radius

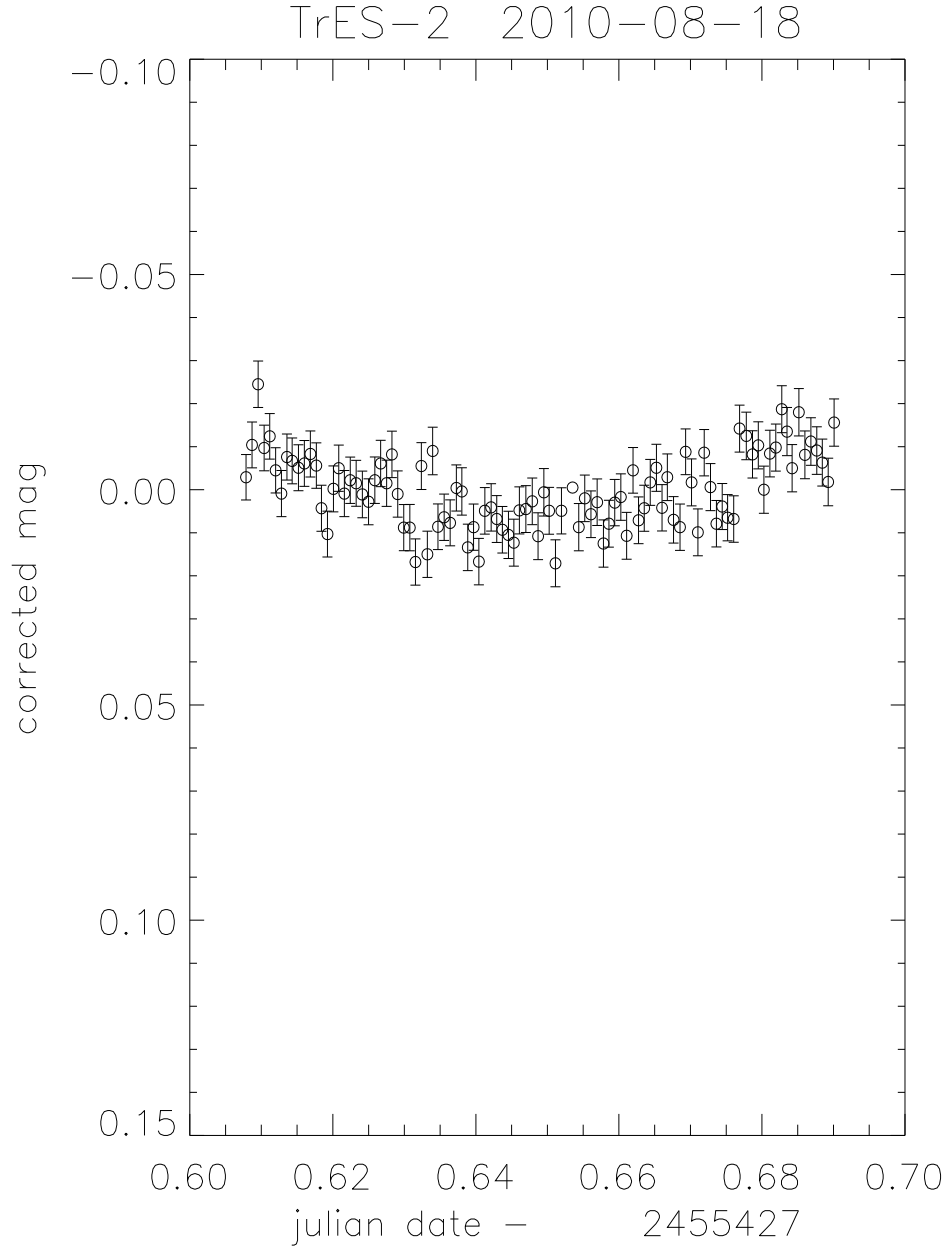


Fig. 3.— TrES-2/2010-08-18 Lightcurve with a 10 pixel star radius, and a 15 and 35 pixel inner and outer sky radius respectively

APPENDIX C

STAR FIELD IMAGES

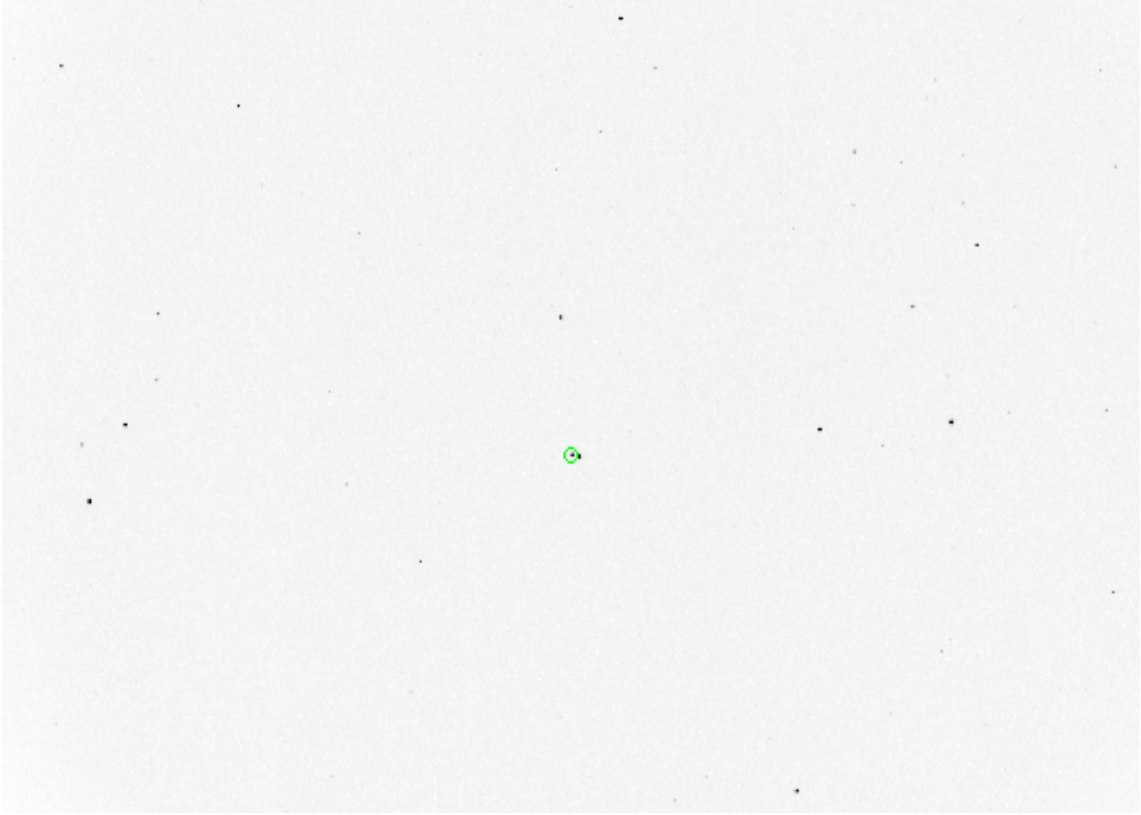


Figure C1: A STEPUP image of HAT-P-1. HAT-P-1b is a 0.524 Jupiter-Mass, 1.217 Jupiter-Radius planet orbiting a GV star 139 pc away at RA: 22:57:47 Dec:+38:40:30. HAT-P-1b orbits at a semi-major axis of 0.05535 AU, with an eccentricity < 0.067 and an orbital period of 4.4652934 days (<http://exoplanet.eu/planet.php?p1=HAT-P-1&p2=b>) STEPUP has observed this target once in December 2009.

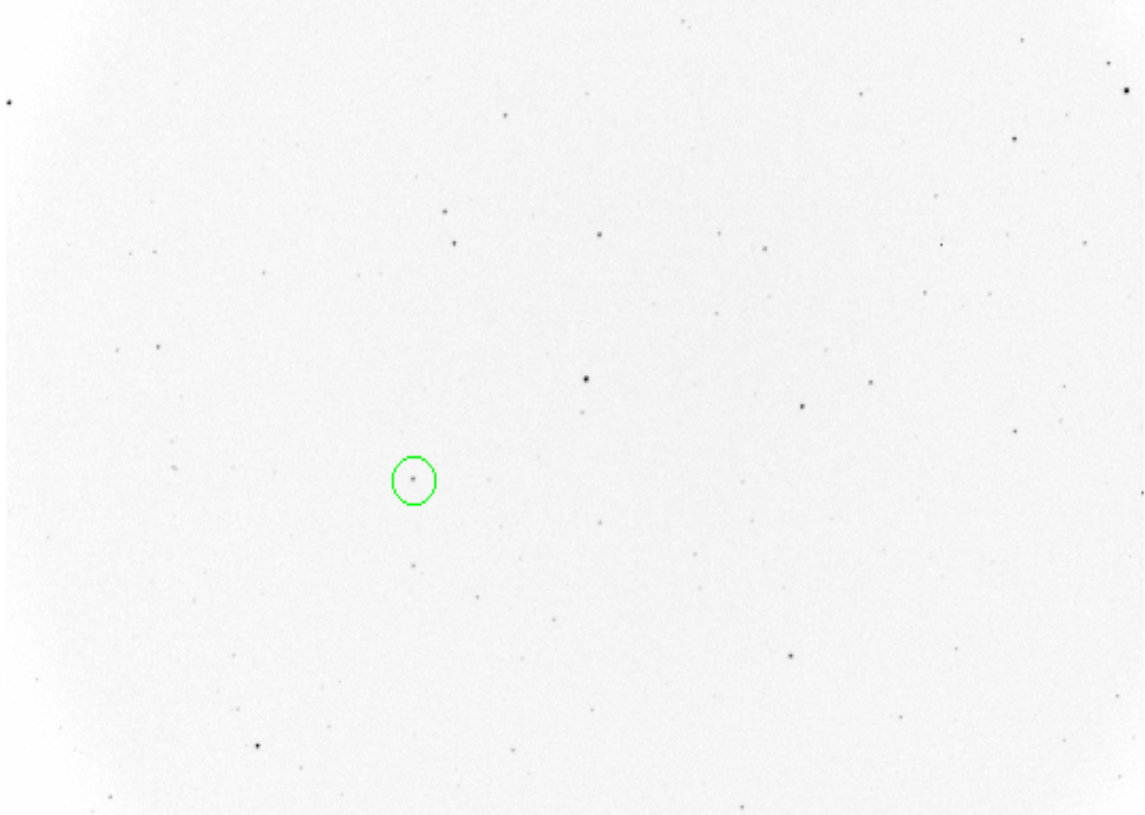


Figure C2: A STEPUP image of HAT-P-9. HAT-P-9b is a 0.67 Jupiter-Mass, 1.4 Jupiter-Radius planet orbiting an F star 480 pc away at RA: 07:20:40 Dec:+37:08:26. HAT-P-9b orbits at a semi-major axis of 0.053 AU, with an approximately zero eccentricity and an orbital period of 3.922814 days (<http://exoplanet.eu/planet.php?p1=HAT-P-9&p2=b>) STEPUP has observed this target once in November 2009.

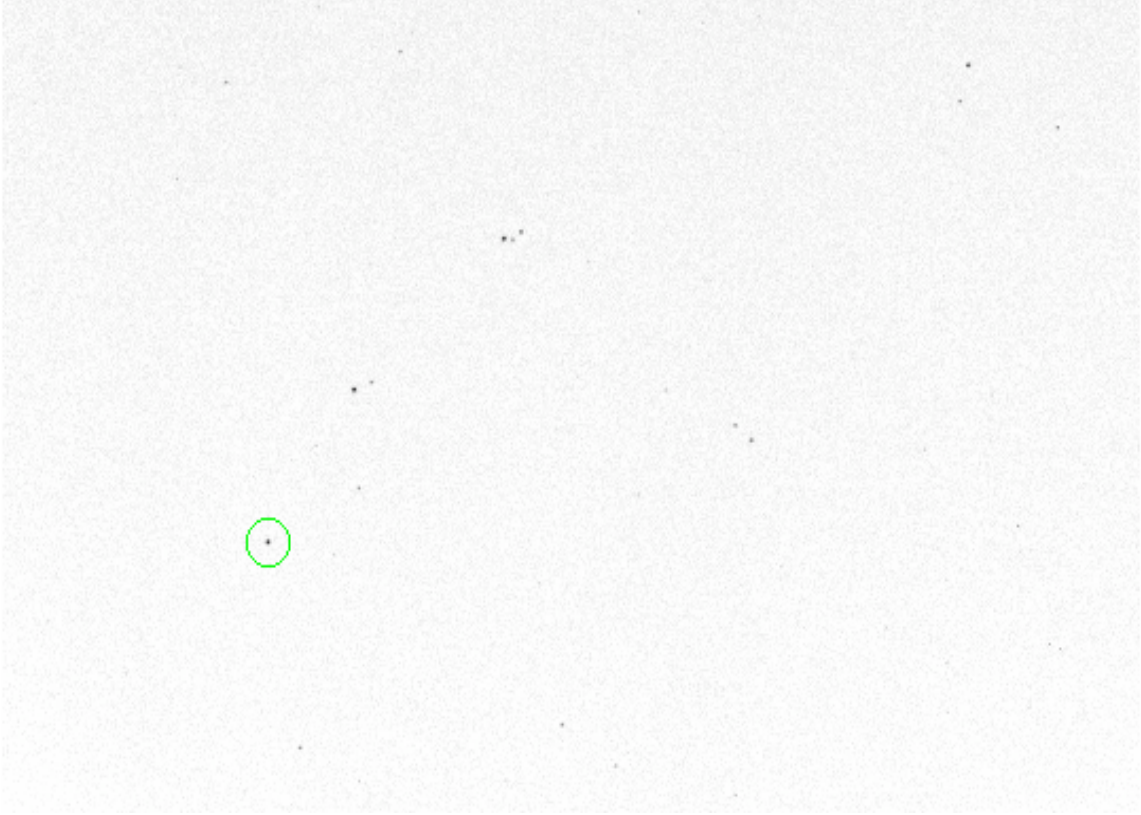


Figure C3: A STEPUP image of HAT-P-13. HAT-P-13b is a 0.85 Jupiter-Mass, 1.28 Jupiter-Radius planet orbiting a GIV star 214 pc away at RA: 08:39:32 Dec:+47:21:07. HAT-P-13b orbits at a semi-major axis of 0.0426 AU, with an eccentricity of 0.0142 and an orbital period of 2.916243 days (<http://exoplanet.eu/planet.php?p1=HAT-P-13&p2=b>) STEPUP has observed this target twelve times in March and April 2010.



Figure C4: A STEPUP image of HD80606b. HD80606b is a 3.94 Jupiter-Mass, 0.921 Jupiter-Radius planet orbiting a GV star 58.4 pc away at RA: 09:22:37 Dec:+50:36:13. HD80606b orbits at a semi-major axis of 0.449 AU, with an eccentricity of 0.93366 and an orbital period of 111.43637 days (<http://exoplanet.eu/planet.php?p1=HD+80606&p2=b>) STEPUP has observed this target five times in September 2009, January 2010 and April 2010.

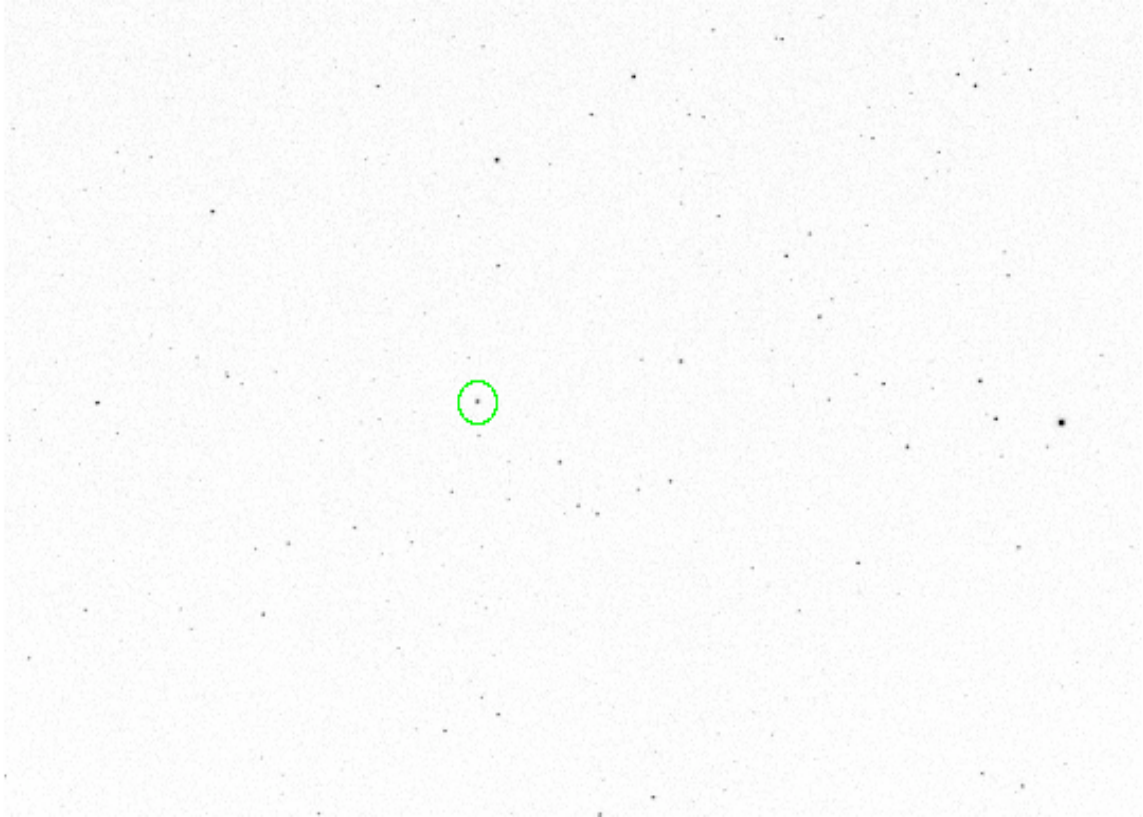


Figure C5: A STEPUP image of TrES-2. TrES-2b is a 1.253 Jupiter-Mass, 1.169 Jupiter-Radius planet orbiting a GV star 220 pc away at RA: 19:07:14 Dec:+49:18:59. TrES-2 orbits at a semi-major axis of 0.03556 AU, with an approximately zero eccentricity and an orbital period of 2.470614 days (<http://exoplanet.eu/planet.php?p1=TrES-2&p2=>) STEPUP has observed this target twice, once in August 2010 and once in October 2010.

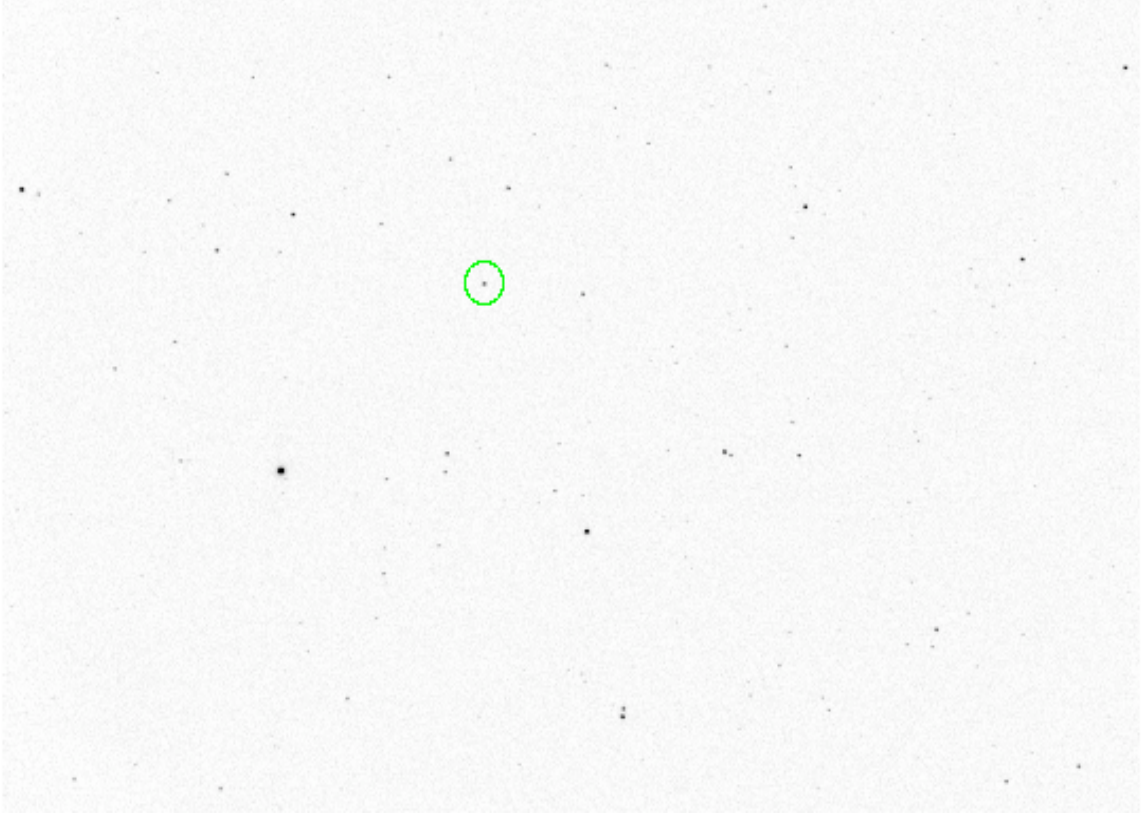


Figure C6: A STEPUP image of WASP-2. WASP-2b is a 0.847 Jupiter-Mass, 1.079 Jupiter-Radius planet orbiting a KIV star 144 pc away at RA: 20:30:54 Dec:+06:25:46. WASP-2b orbits at a semi-major axis of 0.03138 AU, with an approximately zero eccentricity and an orbital period of 2.470614 days (<http://exoplanet.eu/planet.php?p1=WASP-2&p2=b>) STEPUP has observed this target once in October 2010.

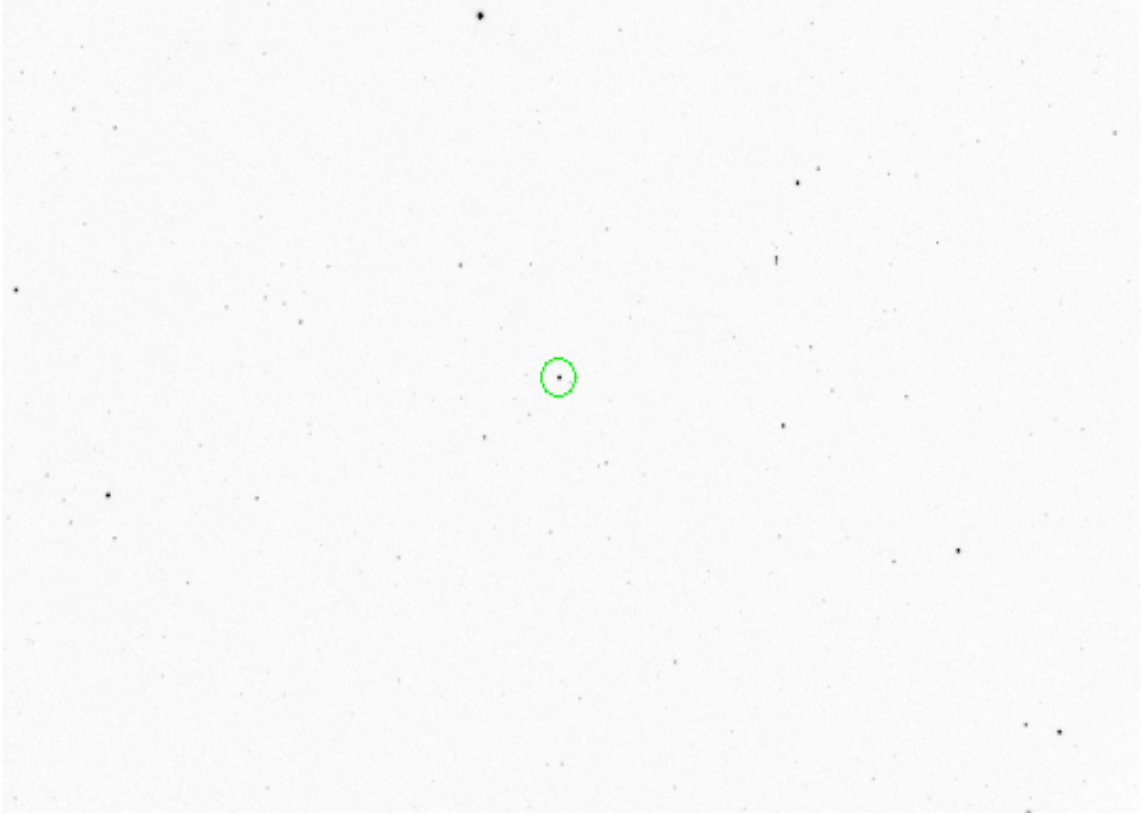


Figure C7: A STEPUP image of WASP-3b. WASP-3b is a 2.06 Jupiter-Mass, 1.454 Jupiter-Radius planet orbiting a F7V star 223 pc away at RA: 18:34:32 Dec:+35:39:42. WASP-3b orbits at a semi-major axis of 0.0313 AU, with an approximately zero eccentricity and an orbital period of 1.8468372 days (<http://exoplanet.eu/planet.php?p1=WASP-3&p2=b>) STEPUP has observed this target once in May 2011.

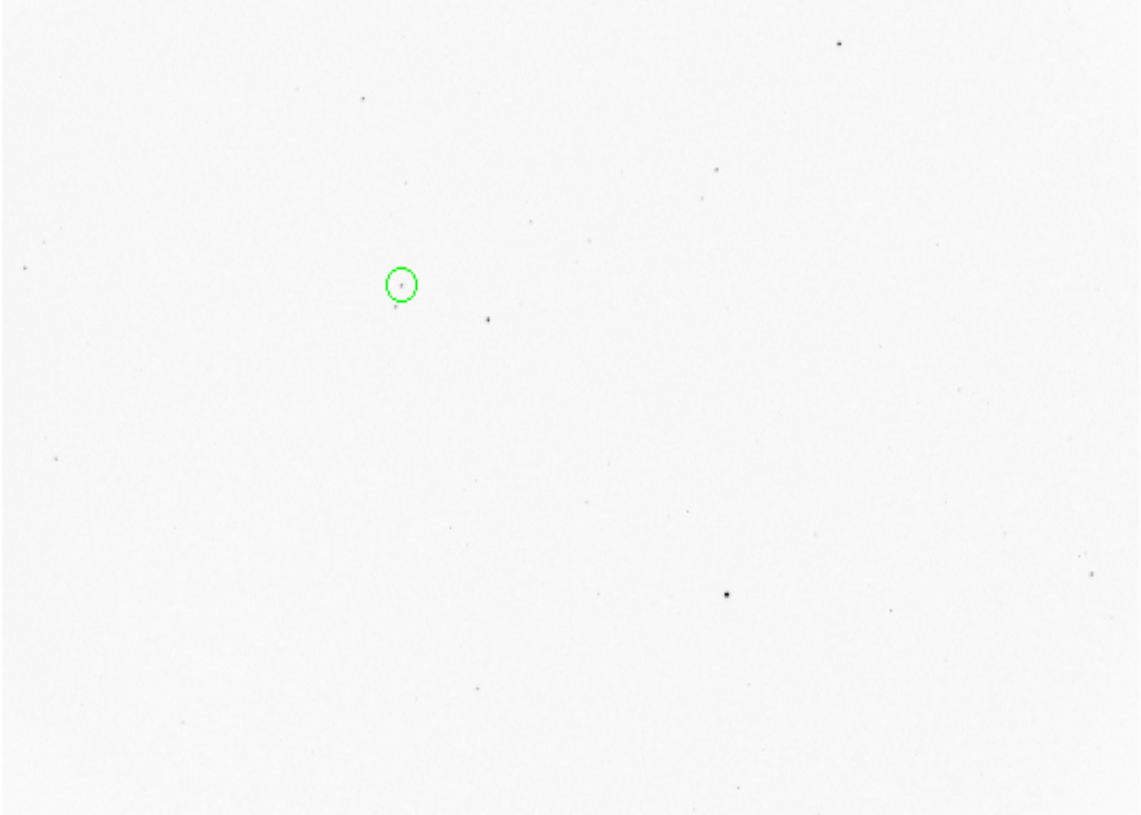


Figure C8: An image from my data of XO-2b. XO-2b is a 0.57 Jupiter-Mass, 0.973 Jupiter-Radius planet orbiting a KV star 149 pc away at RA: 07:48:07 Dec:+50:13:33. XO-2b orbits at a semi-major axis of 0.0369 AU, with an approximately zero eccentricity and an orbital period of 2.615838 days (<http://exoplanet.eu/planet.php?p1=XO-2&p2=b>) I observed this target once prior to the creation of STEPUP, in February 2009.

APPENDIX D

LIGHTCURVES OF MARVELS TARGETS

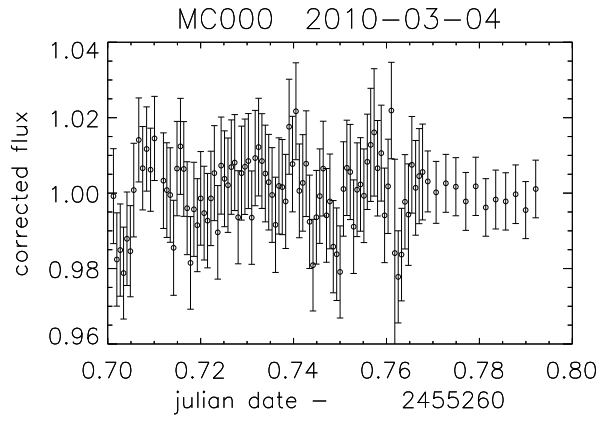


Figure D1: A STEPUP Lightcurve of a MC000 from March 4, 2010.

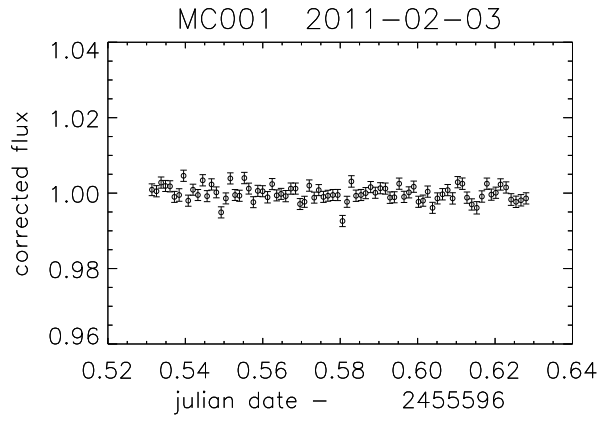


Figure D2: A STEPUP Lightcurve of a MC001 from February 3, 2011.

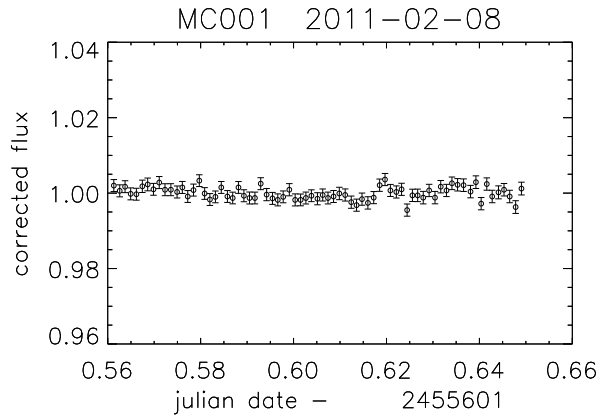


Figure D3: A STEPUP Lightcurve of a MC001 from February 8, 2011.

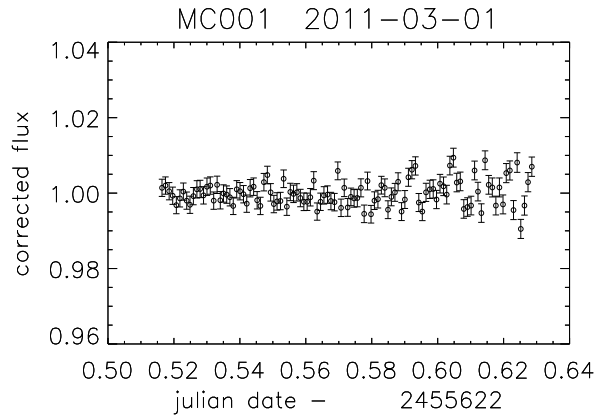


Figure D4: A STEPUP Lightcurve of a MC001 from March 1, 2011.

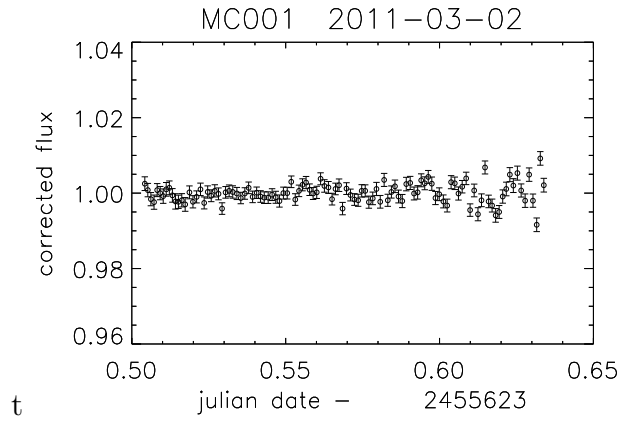


Figure D5: A STEPUP Lightcurve of a MC001 from March 2, 2011.

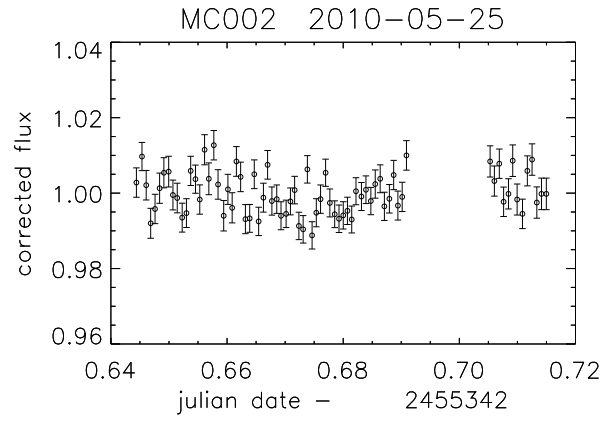


Figure D6: A STEPUP Lightcurve of a MC002 from May 25, 2010.

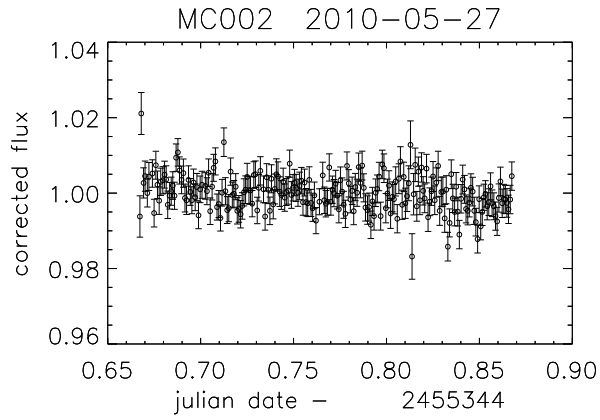


Figure D7: A STEPUP Lightcurve of a MC002 from May 27, 2010.

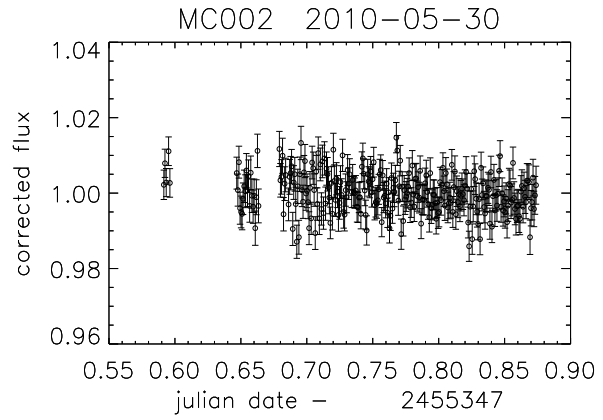


Figure D8: A STEPUP Lightcurve of a MC002 from May 30, 2010.

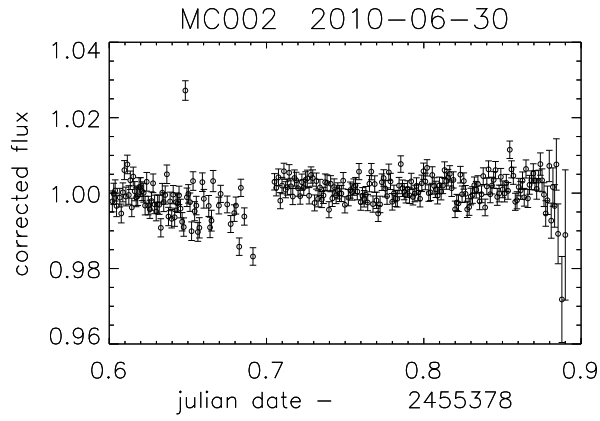


Figure D9: A STEPUP Lightcurve of a MC002 from June 30, 2010.

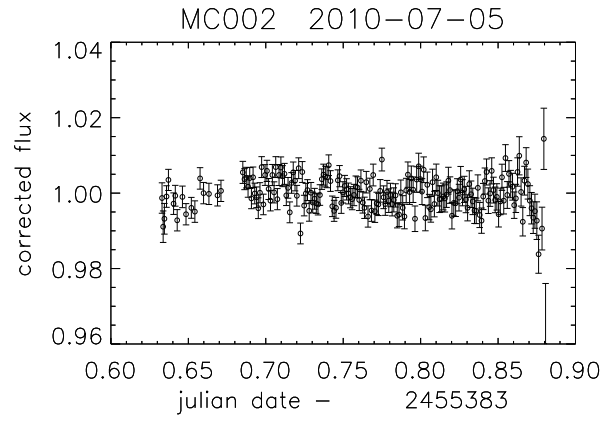


Figure D10: A STEPUP Lightcurve of a MC002 from July 5, 2010.

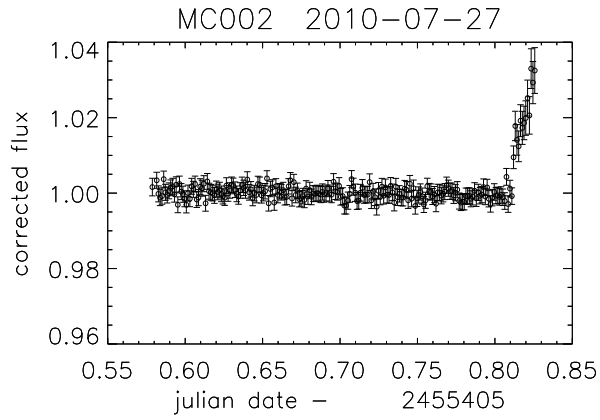


Figure D11: A STEPUP Lightcurve of a MC002 from July 27, 2010.

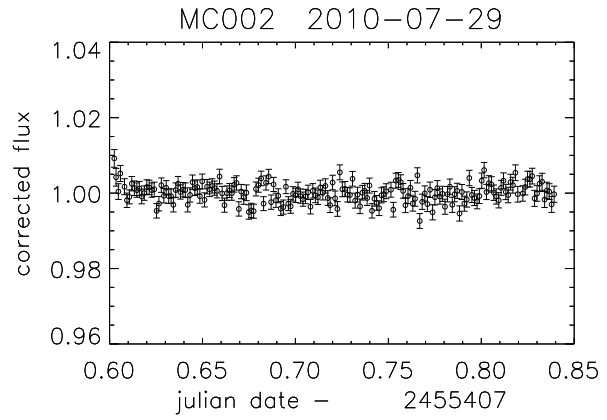


Figure D12: A STEPUP Lightcurve of a MC002 from July 29, 2010.

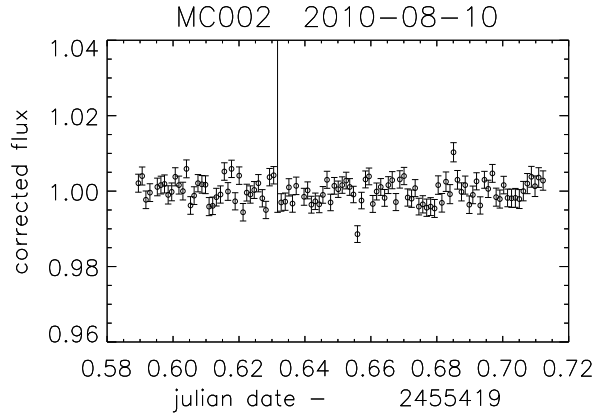


Figure D13: A STEPUP Lightcurve of a MC002 from August 10, 2010.

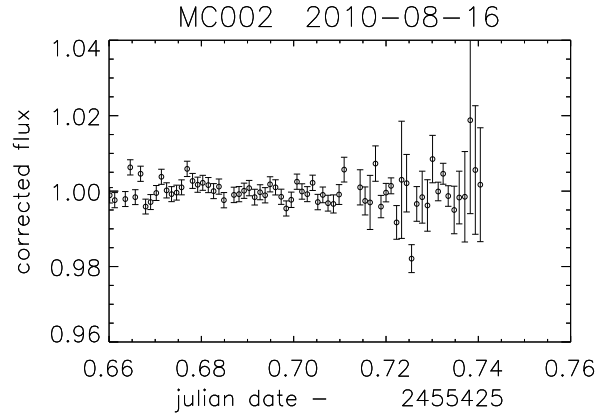


Figure D14: A STEPUP Lightcurve of a MC002 target from August 16, 2010.

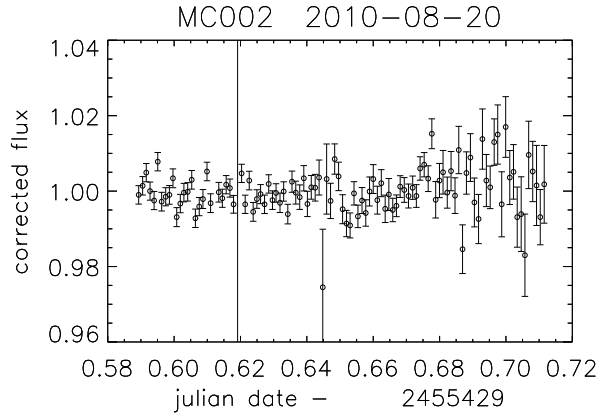


Figure D15: A STEPUP Lightcurve of a MC002 from August 20, 2010.

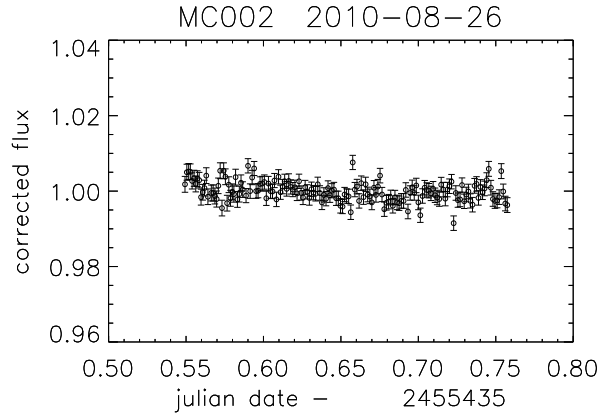


Figure D16: A STEPUP Lightcurve of a MC002 from August 26, 2010.

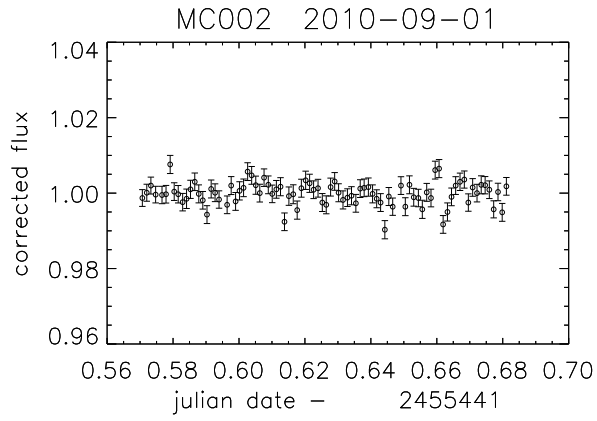


Figure D17: A STEPUP Lightcurve of a MC002 from September 1, 2010.

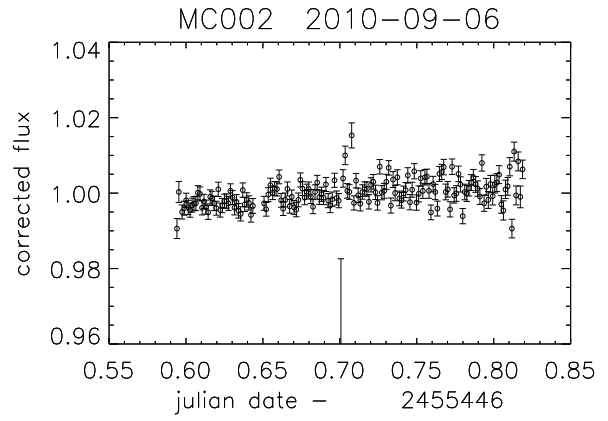


Figure D18: A STEPUP Lightcurve of a MC002 from September 6, 2010.

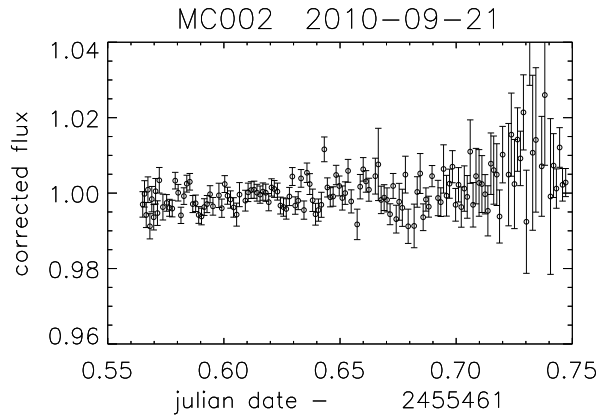


Figure D19: A STEPUP Lightcurve of a MC002 from September 21, 2010.

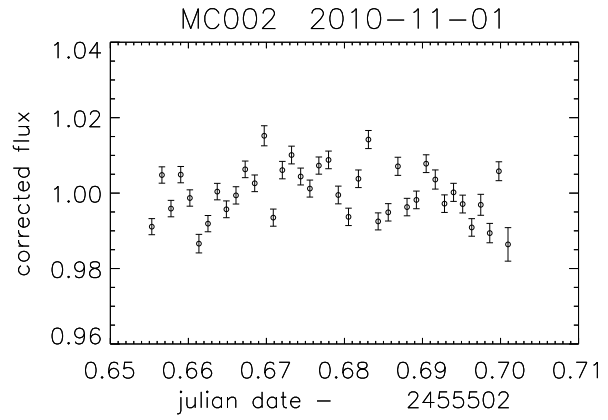


Figure D20: A STEPUP Lightcurve of a MC002 from November 1, 2010.

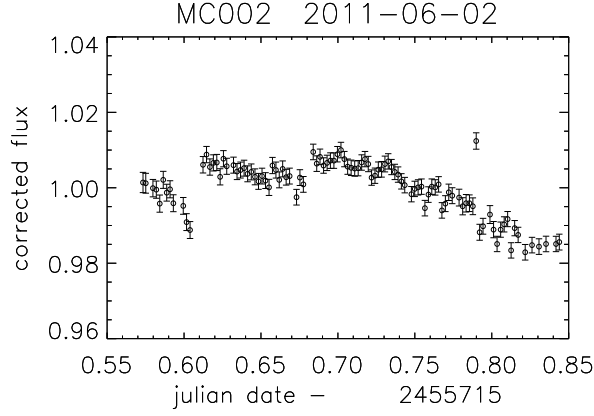


Figure D21: A STEPUP Lightcurve of a MC002 from June 2, 2011. The trends in this lightcurve are artifacts of refocussing, a matter which is currently under investigation.

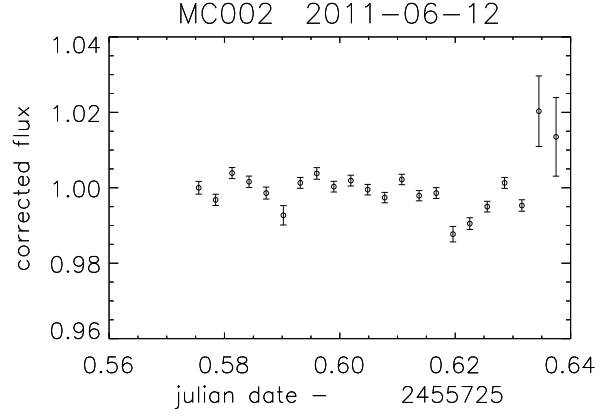


Figure D22: A STEPUP Lightcurve of a MC002 from June 12, 2011.

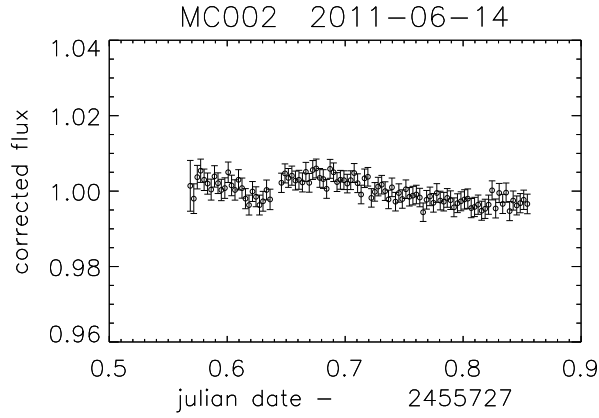


Figure D23: A STEPUP Lightcurve of a MC002 from June 14, 2011. The trends in this lightcurve are artifacts of refocussing, a matter which is currently under investigation.

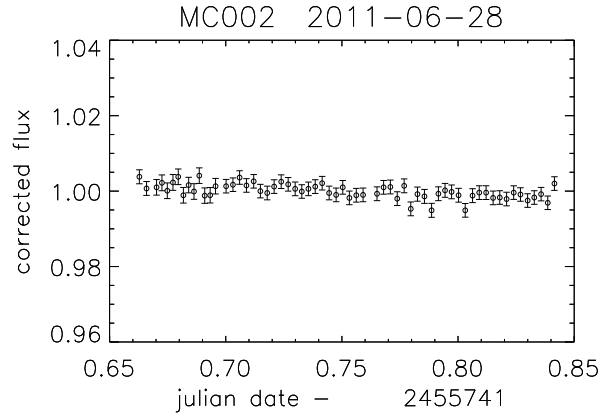


Figure D24: A STEPUP Lightcurve of a MC002 from June 28, 2011.

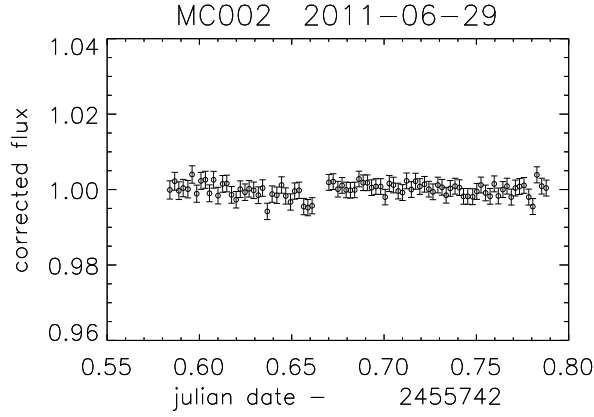


Figure D25: A STEPUP Lightcurve of a MC002 from June 29, 2011.

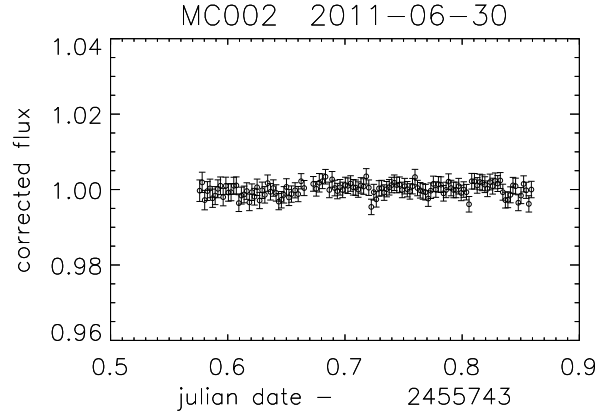


Figure D26: A STEPUP Lightcurve of a MC002 from June 30, 2011.

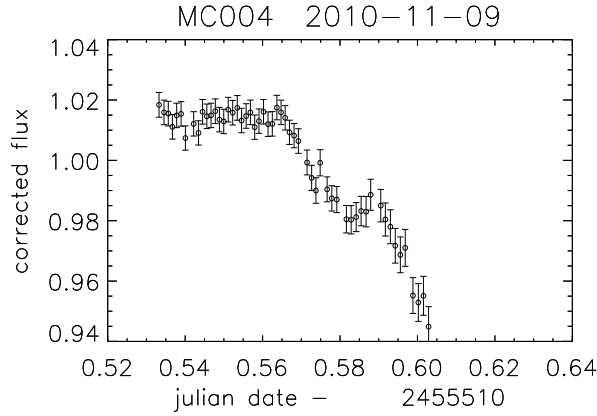


Figure D27: A STEPUP Lightcurve of a MC004 from November 9, 2010. This is an example of data that exhibit an “ingress” just as the images reveal that the flux of the stars disappears. In other words, this is not a true planetary transit ingress.

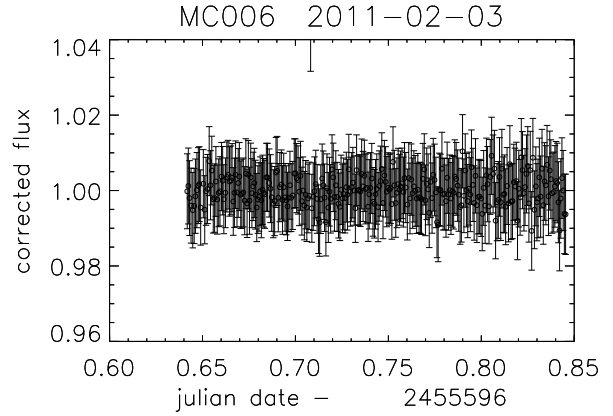


Figure D28: A STEPUP Lightcurve of a MC006 from February 3, 2011.

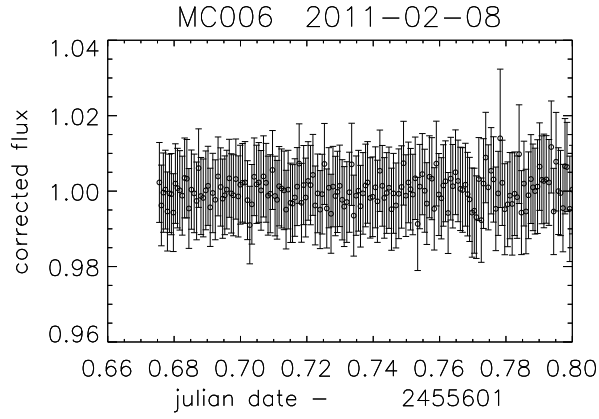


Figure D29: A STEPUP Lightcurve of a MC006 from February 8, 2011.

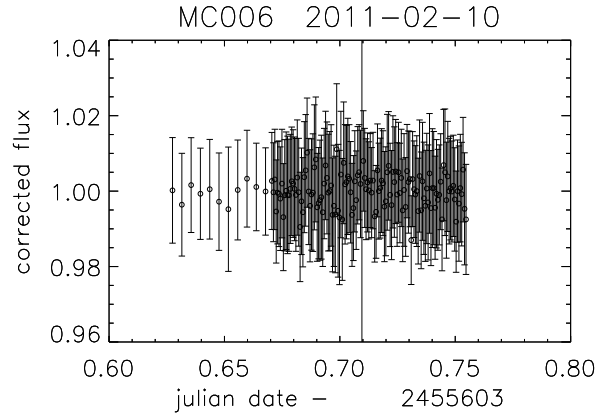


Figure D30: A STEPUP Lightcurve of a MC006 from February 10, 2011.

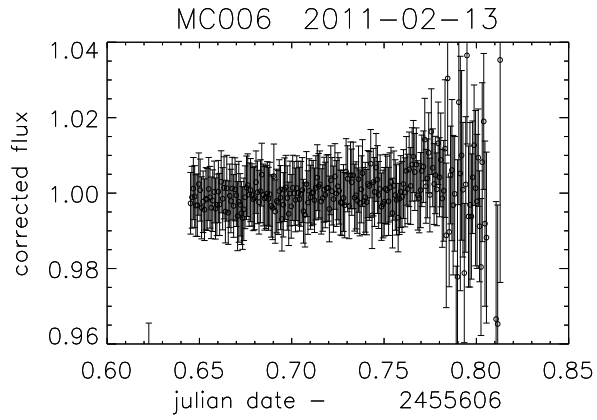


Figure D31: A STEPUP Lightcurve of a MC006 from February 13, 2011.

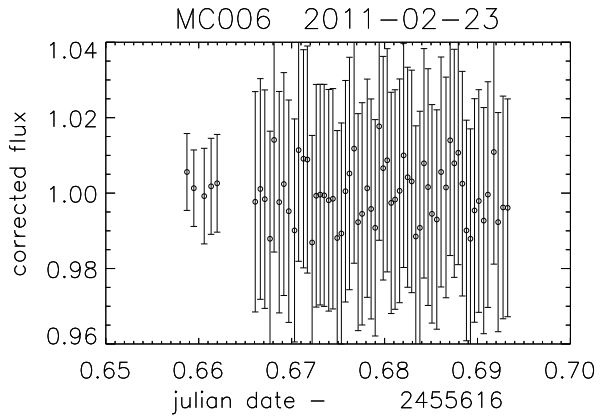


Figure D32: A STEPUP Lightcurve of a MC006 from February 23, 2011.

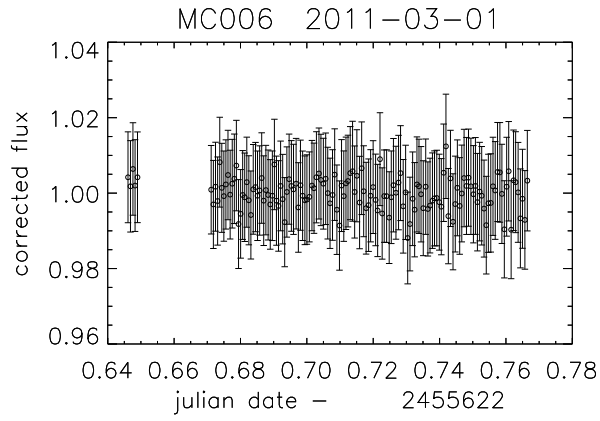


Figure D33: A STEPUP Lightcurve of a MC006 from March 1, 2011.

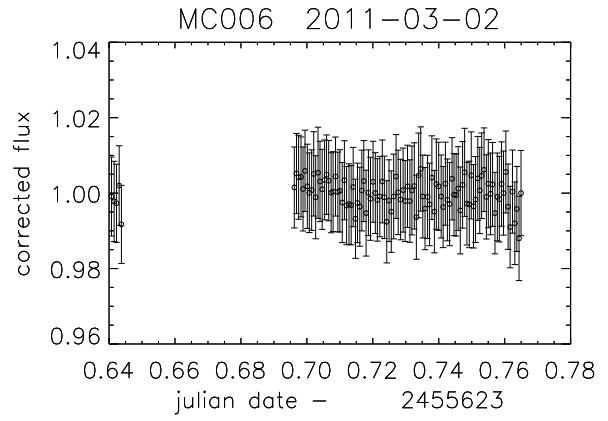


Figure D34: A STEPUP Lightcurve of a MC006 from March 2, 2011.

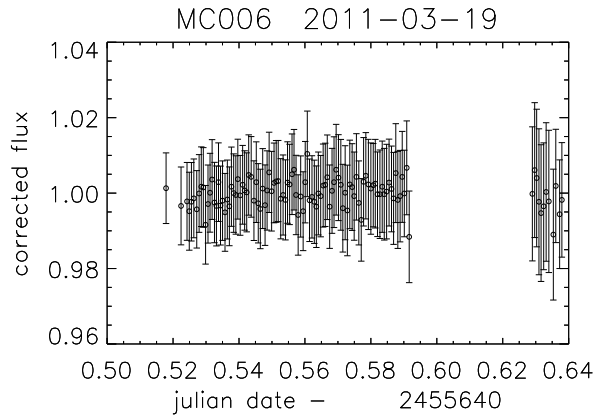


Figure D35: A STEPUP Lightcurve of a MC006 from March 19, 2011.

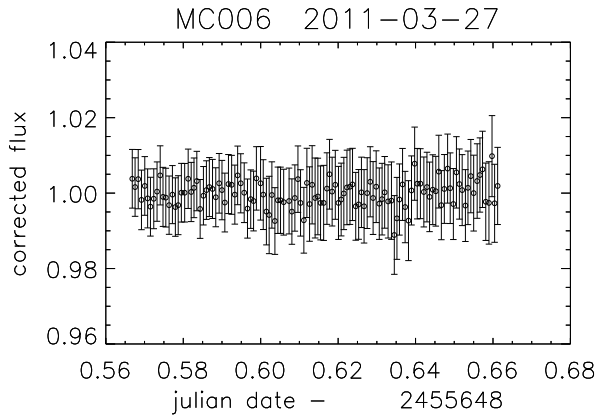


Figure D36: A STEPUP Lightcurve of a MC006 from March 27, 2011.

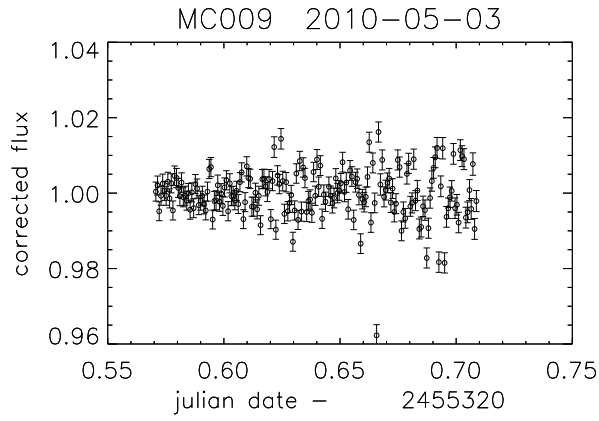


Figure D37: A STEPUP Lightcurve of a MC009 from May 3, 2010.

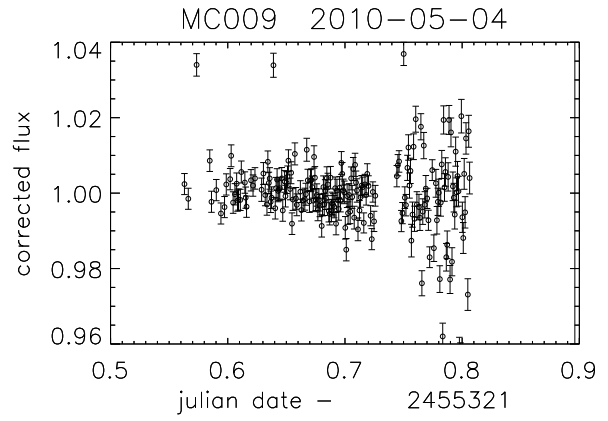


Figure D38: A STEPUP Lightcurve of a MC009 from May 4, 2010.

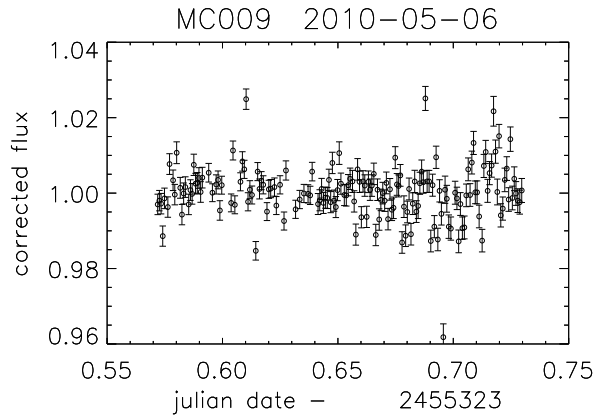


Figure D39: A STEPUP Lightcurve of a MC009 from May 6, 2010.

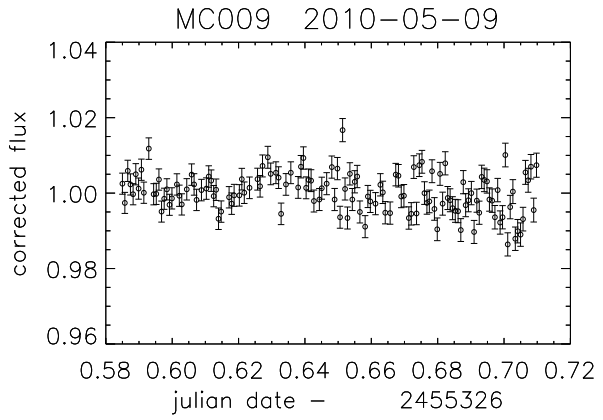


Figure D40: A STEPUP Lightcurve of a MC009 from May 9, 2010.

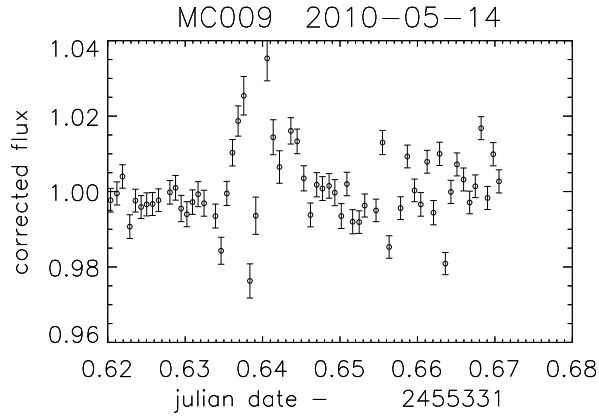


Figure D41: A STEPUP Lightcurve of a MC009 from May 14, 2010.

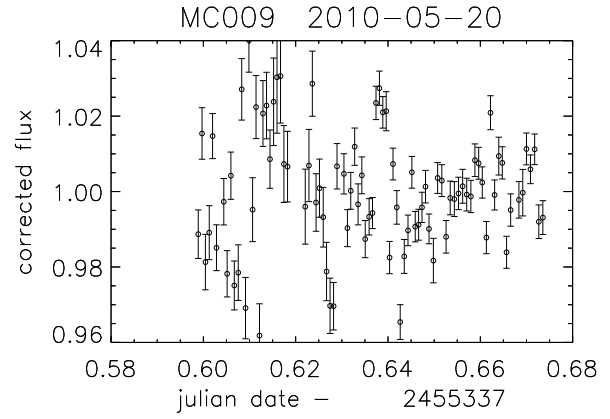


Figure D42: A STEPUP Lightcurve of a MC009 from May 20, 2010.

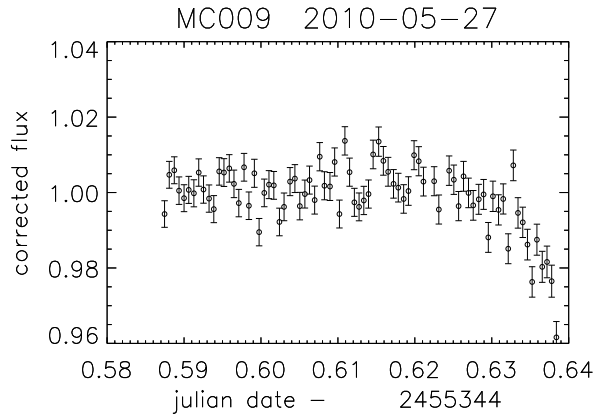


Figure D43: A STEPUP Lightcurve of a MC009 from May 27, 2010. This is an example of data that exhibit an “ingress” just as the images reveal that the flux of the stars disappears. In other words, this is not a true planetary transit ingress.

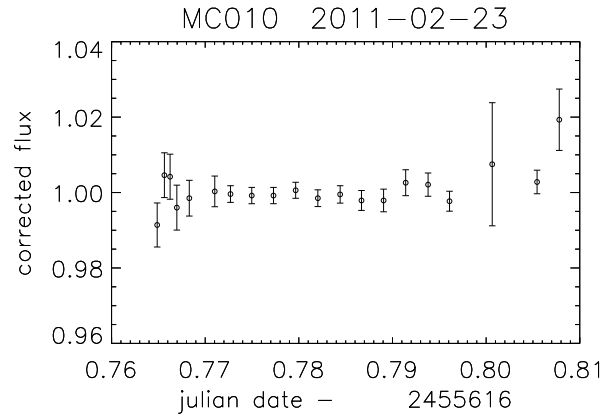


Figure D44: A STEPUP Lightcurve of a MC010 from February 23, 2011.

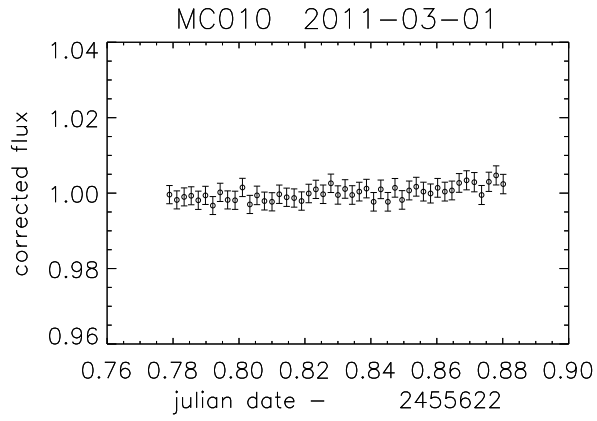


Figure D45: A STEPUP Lightcurve of a MC010 from March 1, 2011.

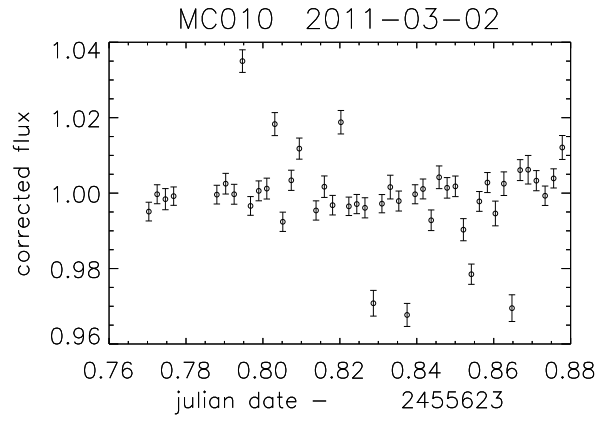


Figure D46: A STEPUP Lightcurve of a MC010 from March 2, 2011.

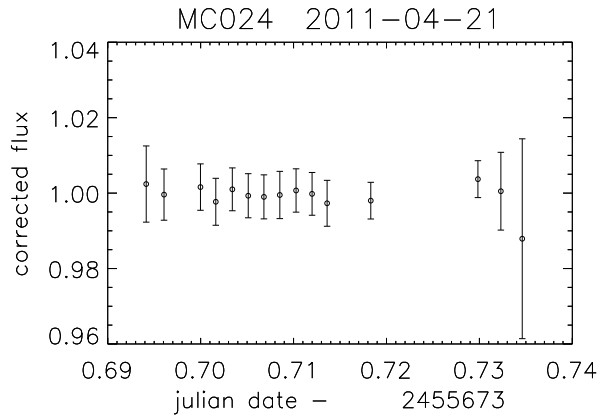


Figure D47: A STEPUP Lightcurve of a MC024 from April 21, 2011.

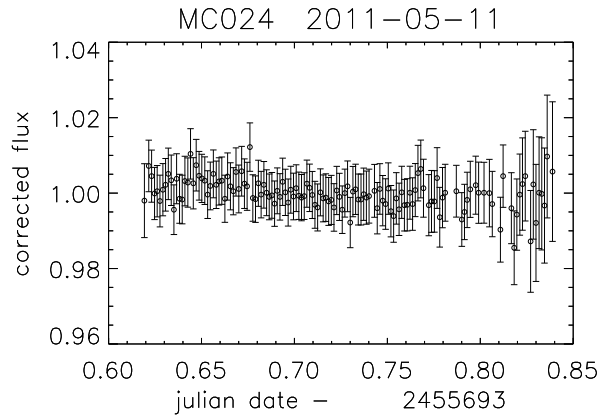


Figure D48: A STEPUP Lightcurve of a MC024 from May 11, 2011.

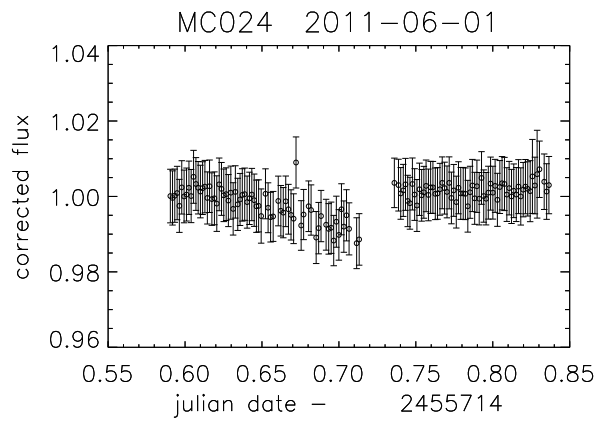


Figure D49: A STEPUP Lightcurve of a MC024 from June 1, 2011. The trends in this lightcurve are artifacts of refocussing, a matter which is currently under investigation.

APPENDIX E

LIGHTCURVES OF KNOWN TARGETS

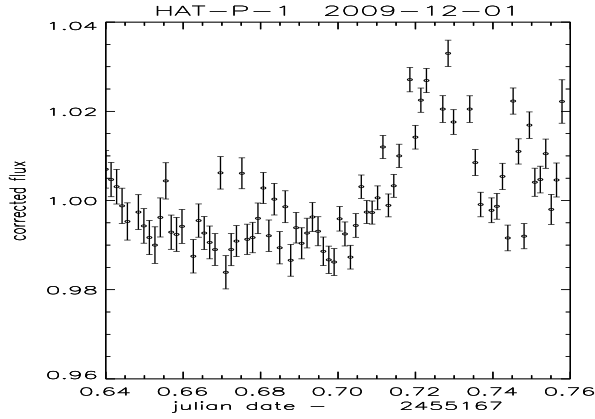


Figure E1: A STEPUP Lightcurve of HAT-P-1 from December 1, 2009. This data set might include a partial transit. GJD=2455167.67 closely coincides with the predicted mid-transit time for HAT-P-1b, being off by only about 8 min. However, this data set suffers from poor tracking and our limited ability to obtain accurate brightness measurements for such a close binary star system using aperture photometry, so it is unclear if we can make any statement about having captured a transit in this data set.

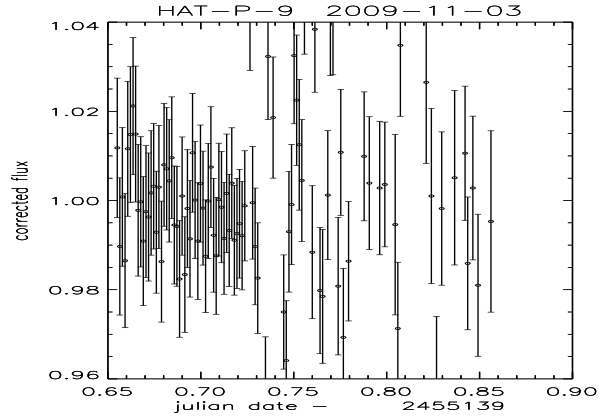


Figure E2: A STEPUP Lightcurve of HAT-P-9 from November 3, 2009. FWHM for this data set was 10.219, the largest of any of our data sets.

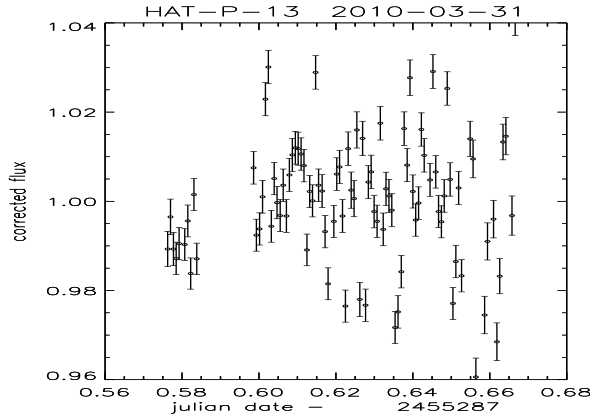


Figure E3: A STEPUP Lightcurve of HAT-P-13 from March 31, 2010. This data set suffered from very poor focus.

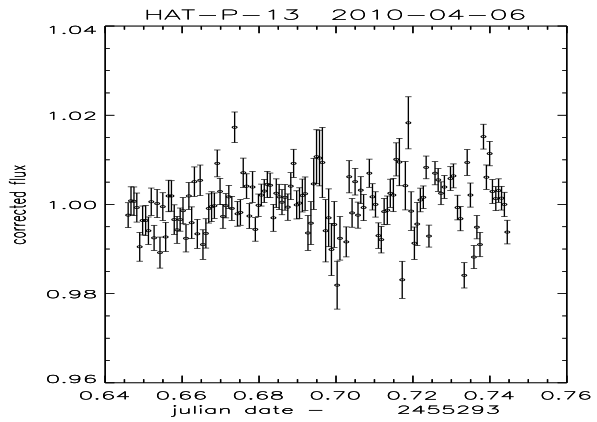


Figure E4: A STEPUP Lightcurve of HAT-P-13 from April 6, 2010.

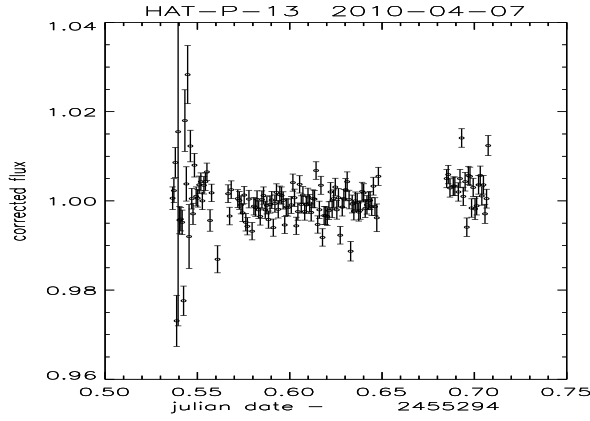


Figure E5: A STEPUP Lightcurve of HAT-P-13 from April 7, 2010. This data set suffered from poor guiding, with elongated and doubled stars in the images. A refocus was done partway through the data set and later the guide star was lost.

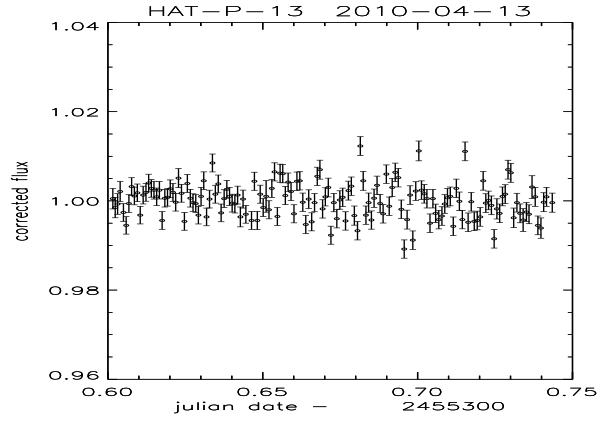


Figure E6: A STEPUP Lightcurve of HAT-P-13 from April 13, 2010.

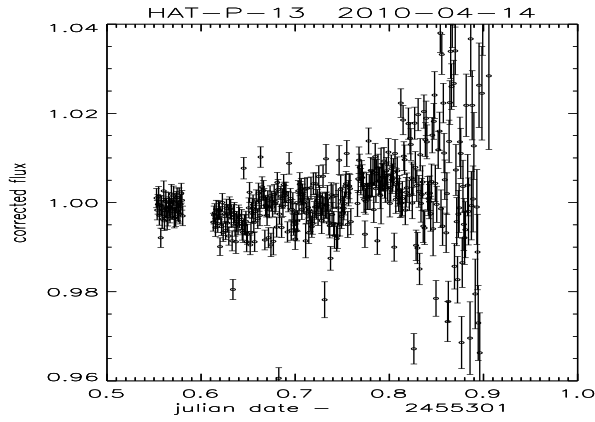


Figure E7: A STEPUP Lightcurve of HAT-P-13 from April 14, 2010. A refocus was done partway through the data set. Then image-taking was left running without supervision.

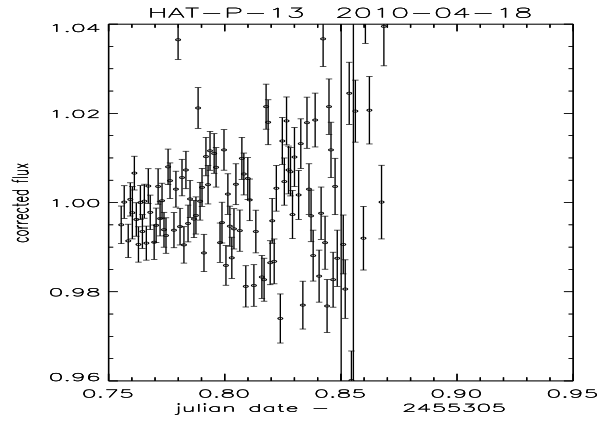


Figure E8: A STEPUP Lightcurve of HAT-P-13 from April 18, 2010. This data set suffered from poor guiding and image-taking was left running without supervision. During that time, flux was gradually lost until stars all but disappeared near the end of the data set.

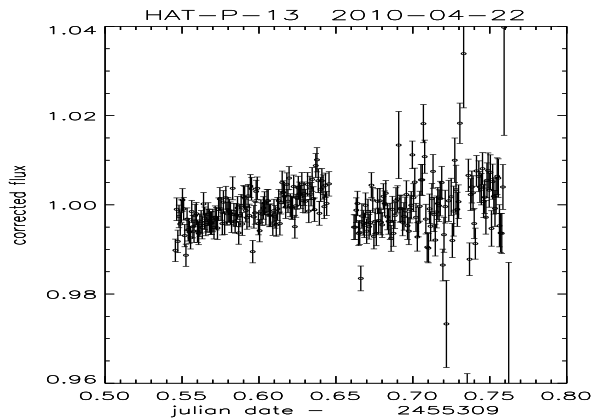


Figure E9: A STEPUP Lightcurve of HAT-P-13 from April 22, 2010. A refocus was done partway through the data set. Then image-taking was left running without supervision.

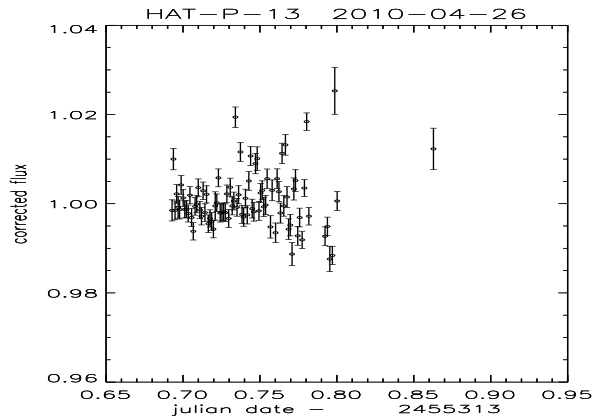


Figure E10: A STEPUP Lightcurve of HAT-P-13 from April 26, 2010. The observing report from this night mentions that weather conditions worsened and guide star was lost about half-way through the data set.

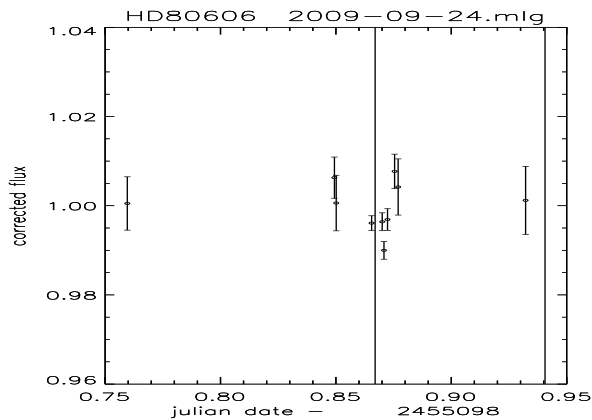


Figure E11: A STEPUP lightcurve of HD80606 from our attempt at the September 23, 2009 collaborative observing effort. Weather conditions were not at all conducive to observing and very little data was salvagable.

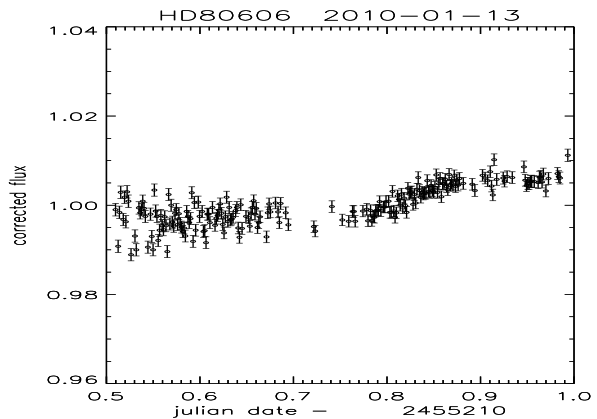


Figure E12: A STEPUP lightcurve of HD80606 from the January 13, 2010 collaborative observing effort. This lightcurve shows a partial transit of HD80606b from that night and is a result of our individual analysis, and does not reflect the fitting done by the collaboration.

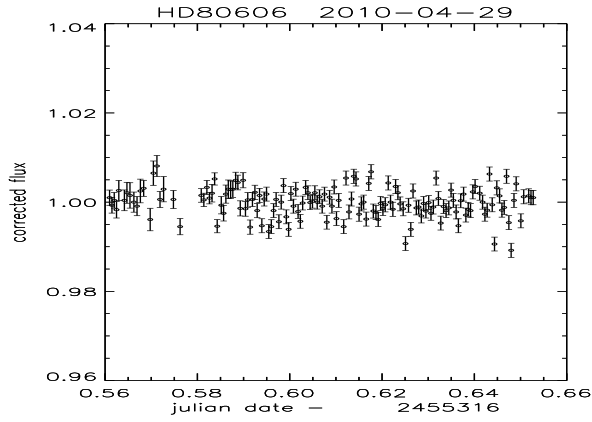


Figure E13: A STEPUP lightcurve of HD80606 from April 29, 2010. This data was purposely taken during an out-of-transit phase of the system to serve as a baseline for the collaborative observing effort.

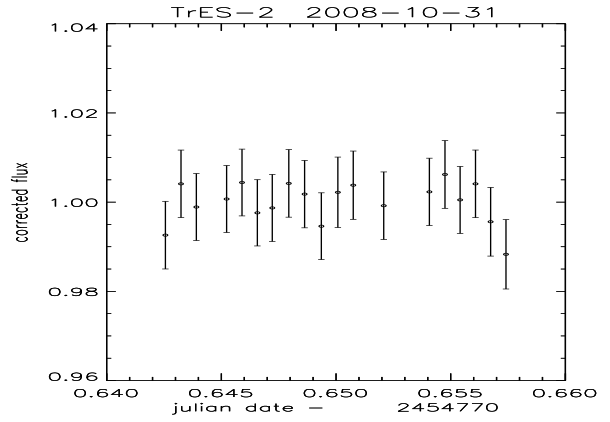


Figure E14: A recent lightcurve from the data I obtained as an undergrad of TrES-2 from October 31, 2008.

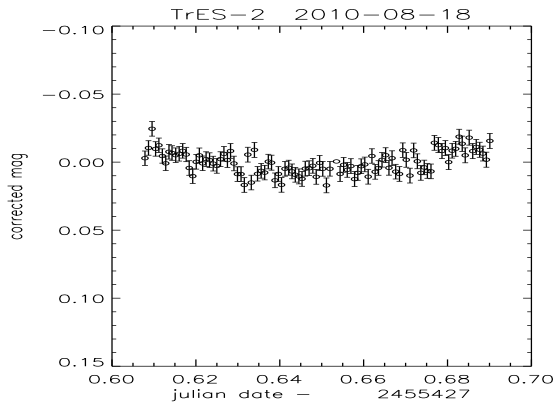


Figure E15: A STEPUP lightcurve of a TrES-2 from August 18, 2010, containing a full transit of the planet TrES-2b.

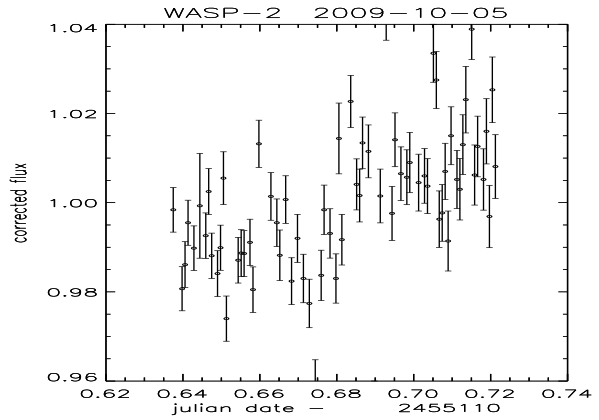


Figure E16: A STEPUP Lightcurve of a WASP-2 from October 5, 2009.

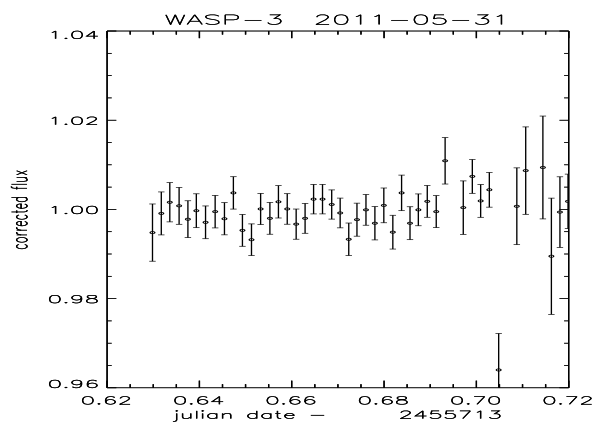


Figure E17: A STEPUP Lightcurve of a WASP-3 from May 31, 2011.

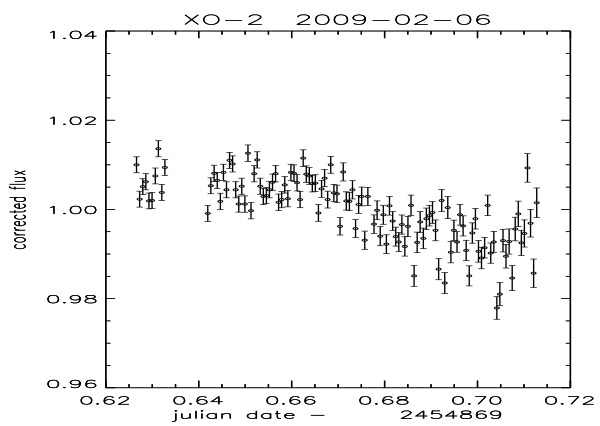


Figure E18: Most recent lightcurve of the XO-2b partial transit I obtained as an undergraduate on February 6, 2009.

APPENDIX F

DATA FILES OF KNOWN TARGETS

HAT-P-1.2009-12-01.initial.flux.abridged.dat

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#GJD	target	reference1	reference2	error	ref.1err.	ref.2err.		
2455167.6400199998		85574.1797	53471.0664	105990.3984	272.27801514	223.45658875	292.18942261	
2455167.6413900000		98571.7656	61921.2812	122171.6016	288.26004028	233.01411438	309.16784668	
2455167.6428100001		96391.2812	60119.5625	120188.4531	283.72332764	232.23600769	307.53973389	
2455167.6442200001		94246.0781	59679.3750	117380.9766	285.67749023	231.22926331	305.75265503	
2455167.6455999999		84866.3516	53454.6055	106542.5000	270.87023926	222.28085327	292.80557251	
2455167.6470100000		98034.0000	53921.4219	107507.7969	286.29571533	223.22039795	293.98925781	
2455167.6484400001		95626.0000	60348.0273	119561.1484	284.93923950	232.00950623	307.45092773	
2455167.6498500002		96237.0391	60835.1289	120791.8125	285.57717896	232.60311890	308.54074097	
2455167.6512699998		96667.5312	60990.8320	121923.5312	285.06912231	232.86973572	309.06597900	
2455167.6527100001		87412.1406	55351.6094	110336.9219	276.23138428	227.11108398	298.07601929	
2455167.6540999999		79660.0000	50428.2383	99619.5078	266.89379883	220.86889648	285.62506104	
2455167.6555200000		91188.1406	56335.8086	114032.5312	280.28762817	229.02343750	302.64785767	
2455167.6569099999		97081.5391	61320.4297	122155.8906	285.51589966	233.90328979	310.63101196	
2455167.6582900002		98772.6484	62359.4844	124394.7031	289.41363525	235.77763367	312.68188477	
2455167.6597000002		98804.3125	61976.1250	124508.4062	287.88085938	233.47541809	312.89505005	
2455167.6612000000		99.0000	99.0000	99.0000	287.88085938	233.47541809	312.89505005	
2455167.6626200001		99800.5312	63004.1914	126639.9062	289.27420044	236.07247925	313.88290405	

2455167.6639899998	102284.7891	64182.3867	128621.2969	292.35565186	236.31118774	315.14352417
2455167.6654400001	103207.6562	64419.6289	130678.7891	294.47036743	237.85006714	319.05175781
2455167.6668500002	104214.6016	65164.6836	132238.3438	295.23895264	239.62068176	320.57632446
2455167.6682300000	109323.4453	69111.3203	138320.4062	300.86123657	244.33758545	326.90930176
2455167.6696400000	110581.5234	68268.1719	137955.0000	303.68725586	244.35304260	327.67526245
2455167.6710199998	101750.0625	64222.5078	129838.8672	294.49227905	239.27299500	319.59259033
2455167.6724000000	107730.4375	67761.3594	136630.5938	301.00277710	244.71095276	327.00869751
2455167.6737600002	115159.5312	72716.5859	145360.2031	308.00881958	250.02244568	335.70077515
2455167.6751700002	120199.7891	74366.2891	149822.0000	315.07098389	252.91868591	339.88760376
2455167.6765500000	120860.8359	75530.3516	153258.5781	315.46038818	255.97103882	343.78811646
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2455167.6793200001	121215.4141	75894.1953	152485.2969	319.89431763	255.50117493	344.74398804
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2455167.6835300000	116791.9688	72385.0078	146698.3906	314.50753784	257.46261597	341.62893677
2455167.6849400001	111403.5781	70053.8125	141239.5625	310.06298828	256.21151733	336.25808716
2455167.6863699998	115652.1172	72065.1875	145255.8594	315.56771851	256.62457275	340.96942139
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2455139.8115500002	206734.2500	NaN	NaN	633.87292480	NaN	NaN
2455139.8129599998	209728.0938	98613.8594	NaN	625.06994629	617.41137695	NaN
2455139.8143400000	188705.7188	85018.9766	NaN	643.88769531	629.90795898	NaN
2455139.8157299999	179384.6875	94833.1953	59507.1758	625.02490234	613.55511475	513.23498535
2455139.8171199998	NaN	90927.6797	52485.9141	NaN	624.39410400	516.47875977
2455139.8185200002	178794.4375	100785.9922	50954.6250	607.35394287	620.51525879	507.73129272
2455139.8199100001	190351.8125	NaN	NaN	636.56762695	NaN	NaN
2455139.8213000000	184509.8125	88590.2578	47336.8438	614.58563232	609.46234131	500.56292725
2455139.8226999999	NaN	79632.3203	47157.8164	NaN	631.78790283	556.52844238
2455139.8240700001	183726.0938	81786.9844	57007.7773	690.61706543	671.91931152	577.86096191
2455139.8254600000	NaN	65284.9766	NaN	NaN	681.08660889	NaN
2455139.8268400002	139565.4688	70898.6250	40131.2227	665.59283447	660.85266113	602.43920898
2455139.8282400002	NaN	NaN	35425.0820	NaN	NaN	562.98681641
2455139.8296300001	190961.8594	84444.1406	60215.3164	635.92108154	617.29528809	523.56634521
2455139.8310199999	NaN	88070.8438	47809.9023	NaN	610.87524414	515.81750488
2455139.8324000002	NaN	82105.3047	NaN	NaN	643.13787842	NaN
2455139.8338000001	NaN	78961.1016	NaN	NaN	654.62207031	NaN
2455139.8351699999	NaN	79150.8125	46767.9453	NaN	644.54327393	554.57757568
2455139.8365699998	179969.0000	81662.4922	53735.8945	652.97674561	651.35589600	570.88708496
2455139.8379600001	181266.5938	88843.9922	NaN	633.68029785	625.62530518	NaN
2455139.8393999999	192799.3438	90398.4844	NaN	615.99548340	593.65380859	NaN
2455139.8407999999	144519.7188	76124.2422	46145.9062	598.62628174	614.22918701	508.54312134
2455139.8421999998	214573.8906	95890.3203	64665.9492	616.01336670	591.76812744	503.32061768

2455139.8435999998	210484.1562	94724.0859	66719.7734	616.65509033	605.80639648	508.86047363
2455139.8450000002	NaN	82439.1094	NaN	NaN	610.63110352	NaN
2455139.8463800000	202522.6094	91746.5469	60967.8398	621.04010010	609.82910156	519.31610107
2455139.8477699999	182425.3594	NaN	53691.5195	611.02526855	NaN	522.35559082
2455139.8491600002	193828.4062	88050.8438	61355.2891	602.80419922	597.03057861	518.41418457
2455139.8505600002	138075.3281	80002.1016	46678.2109	570.73199463	592.09399414	499.93572998
2455139.8519400000	174235.1719	83936.7734	NaN	610.78167725	594.57373047	NaN
2455139.8533299998	NaN	85610.1250	NaN	NaN	613.43603516	NaN
2455139.8547100001	162056.9062	82405.7109	49301.0352	595.09558105	599.70849609	499.49386597
2455139.8561100001	158898.1094	79798.6484	40928.2305	618.31079102	615.45178223	519.74346924
2455139.8574999999	187501.5938	80575.1953	NaN	626.50878906	622.05810547	NaN
2455139.8588999999	NaN	NaN	NaN	NaN	NaN	NaN
2455139.8602800001	NaN	79954.7969	45284.9727	NaN	607.33764648	494.32080078
2455139.8616599999	NaN	NaN	39215.0117	NaN	NaN	516.31616211
2455139.8630300001	118213.7344	60855.7266	38968.3203	582.48828125	603.88226318	490.65640259
2455139.8644400002	NaN	66959.4453	NaN	NaN	662.80682373	NaN

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#GJD	target	reference1	reference2	error	ref.1err.	ref.2err.
2455287.5762600000	149908.8906	110030.2812	110030.2812	334.41049194	290.28024292	290.28024292
2455287.5770000000	150610.8594	109746.2734	109746.2734	334.77151489	290.48483276	290.48483276
2455287.5777699999	166773.2500	122406.7891	122406.7891	349.67056274	303.33123779	303.33123779
2455287.5784800001	174373.8125	128256.1484	128256.1484	356.80679321	309.52572632	309.52572632
2455287.5792399999	176485.8750	129385.7109	129385.7109	358.44418335	311.40631104	311.40631104
2455287.5799699998	99.0000	99.0000	99.0000	358.44418335	311.40631104	311.40631104
2455287.5807099999	182201.2500	133598.9844	133598.9844	363.51654053	315.32858276	315.32858276
2455287.5814999999	182255.1562	132930.6719	132930.6719	364.10717773	314.28244019	314.28244019
2455287.5822500000	183992.8750	135803.0938	135803.0938	365.19946289	316.87359619	316.87359619
2455287.5830999999	181301.8281	131446.2656	131446.2656	362.36630249	313.04840088	313.04840088
2455287.5838299999	183748.2188	135164.7812	135164.7812	365.31857300	316.52801514	316.52801514
2455287.5986000001	182050.1875	131211.7500	131211.7500	364.18649292	313.58117676	313.58117676
2455287.5993300001	180590.7031	132138.6719	132138.6719	363.52133179	314.20315552	314.20315552
2455287.6001599999	179163.1875	130906.6406	130906.6406	361.60147095	313.37414551	313.37414551
2455287.6009300002	178326.7969	129356.8359	129356.8359	361.50952148	311.71481323	311.71481323

2455287.6016799998	180916.0156	128421.9922	128421.9922	363.31341553	311.21826172	311.21826172
2455287.6024400000	181716.4531	128095.1953	128095.1953	364.17532349	310.26300049	310.26300049
2455287.6032099999	182895.7812	133557.6719	133557.6719	365.93148804	315.68829346	315.68829346
2455287.6039600000	181643.6719	131227.5469	131227.5469	363.87255859	312.46795654	312.46795654
2455287.6046899999	181350.6562	131728.1719	131728.1719	363.47210693	314.11230469	314.11230469
2455287.6055200002	181540.8906	132248.3281	132248.3281	363.54269409	314.35592651	314.35592651
2455287.6063000001	180509.0781	130600.2891	130600.2891	362.86700439	312.67410278	312.67410278
2455287.6071400000	175295.0938	127704.3828	127704.3828	358.38650513	311.01498413	311.01498413
2455287.6079099998	177768.9844	128331.2422	128331.2422	360.39086914	309.87298584	309.87298584
2455287.6086800001	176254.4062	126668.8750	126668.8750	359.41247559	309.77624512	309.77624512
2455287.6094599999	180449.2969	129478.3594	129478.3594	362.78015137	311.57223511	311.57223511
2455287.6101899999	178774.7188	128299.3594	128299.3594	362.05084229	310.91815186	310.91815186
2455287.6109500001	183658.1406	131962.6406	131962.6406	365.80392456	313.61532593	313.61532593
2455287.6116999998	181570.8594	130796.2500	130796.2500	364.31967163	312.96981812	312.96981812
2455287.6124700001	182272.7188	133807.7656	133807.7656	364.82809448	316.09909058	316.09909058
2455287.6131899999	182064.8906	131914.1406	131914.1406	364.20016479	314.57092285	314.57092285
2455287.6139199999	182373.6562	132412.9062	132412.9062	364.52416992	314.88043213	314.88043213
2455287.6147300000	179948.2344	126993.2969	126993.2969	361.83151245	309.13964844	309.13964844
2455287.6154900002	180463.9531	130564.5859	130564.5859	363.48159790	313.70211792	313.70211792
2455287.6164199999	177917.7969	128898.4844	128898.4844	361.41799927	312.46093750	312.46093750
2455287.6171900001	176793.1562	129250.2422	129250.2422	360.02087402	311.43515015	311.43515015
2455287.6179700000	177201.9531	131093.9219	131093.9219	360.57901001	313.83648682	313.83648682
2455287.6187000000	175219.6562	NaN NaN	359.59063721 NaN NaN			
2455287.6194699998	180862.4375	131916.7969	131916.7969	363.79727173	315.09533691	315.09533691
2455287.6202300000	179696.5156	129689.7266	129689.7266	362.58569336	312.03280640	312.03280640
2455287.6209600000	176786.9688	127393.2422	127393.2422	360.13290405	310.53390503	310.53390503
2455287.6217200002	174100.1719	126839.3125	126839.3125	357.38125610	309.45556641	309.45556641
2455287.6224799999	173673.6094	129144.4297	129144.4297	358.13583374	311.68298340	311.68298340
2455287.6231900002	173610.4375	124591.9375	124591.9375	357.05120850	306.89749146	306.89749146
2455287.6239700001	149752.5938	108473.1016	108473.1016	335.81463623	291.67224121	291.67224121
2455287.6247200002	148586.6875	107829.1250	107829.1250	334.22369385	290.05657959	290.05657959
2455287.6254500002	153603.0312	109777.3906	109777.3906	338.62329102	292.64767456	292.64767456
2455287.6262200000	155985.9062	115812.0859	115812.0859	341.07196045	298.78265381	298.78265381
2455287.6269399999	167695.0781	120076.6875	120076.6875	352.00582886	302.66964722	302.66964722

2455287.6277100001	171971.6406	127856.5781	127856.5781	356.10571289	310.48770142	310.48770142
2455287.6284400001	173960.0000	125776.8281	125776.8281	357.52224731	309.12460327	309.12460327
2455287.6291700001	173549.3594	125198.5000	125198.5000	357.61566162	308.33291626	308.33291626
2455287.6299399999	176564.2344	128501.8984	128501.8984	359.68200684	310.58981323	310.58981323
2455287.6307100002	176802.6562	128959.1016	128959.1016	359.65679932	311.68948364	311.68948364
2455287.6315500000	175957.7500	125571.0859	125571.0859	359.46572876	309.12887573	309.12887573
2455287.6323000002	174536.3125	127541.2344	127541.2344	358.35974121	311.01385498	311.01385498
2455287.6330300001	173030.2188	125292.1328	125292.1328	356.12939453	308.35241699	308.35241699
2455287.6338000000	172966.2344	125447.8594	125447.8594	356.97967529	307.96087646	307.96087646
2455287.6345299999	173484.4219	126219.7422	126219.7422	357.53506470	309.06582642	309.06582642
2455287.6353900000	173458.4688	129620.8750	129620.8750	357.72665405	312.27734375	312.27734375
2455287.6361500002	170580.8594	127016.0625	127016.0625	355.05322266	309.09802246	309.09802246
2455287.6370000001	174829.5000	128992.6016	128992.6016	358.60284424	311.18630981	311.18630981
2455287.6377500002	176153.9844	125862.6875	125862.6875	359.84228516	309.52471924	309.52471924
2455287.6385300001	177298.0000	127701.3828	127701.3828	360.41677856	310.61776733	310.61776733
2455287.6392600001	160943.3125	113712.8359	113712.8359	344.96829224	296.50921631	296.50921631
2455287.6400100002	174830.5000	126664.8438	126664.8438	359.07312012	310.35723877	310.35723877
2455287.6407499998	179462.8594	130861.0312	130861.0312	363.74636841	313.59783936	313.59783936
2455287.6414899998	179514.6719	130397.3281	130397.3281	363.41830444	312.93814087	312.93814087
2455287.6422199998	177258.3594	126672.7500	126672.7500	360.56451416	309.42178345	309.42178345
2455287.6429599999	174436.9062	125370.6797	125370.6797	357.85253906	308.59295654	308.59295654
2455287.6437200001	176794.0938	NaN NaN	360.73400879 NaN NaN			
2455287.6444799998	178066.0000	128687.3438	128687.3438	361.92199707	311.69790649	311.69790649
2455287.6452299999	179218.6719	126459.1094	126459.1094	362.33728027	309.97671509	309.97671509
2455287.6459599999	181767.5156	131121.0469	131121.0469	364.45724487	312.89965820	312.89965820
2455287.6466899998	180714.2500	131521.0312	131521.0312	363.70596313	315.18731689	315.18731689
2455287.6474299999	181915.5625	132708.0156	132708.0156	364.96023560	316.05410767	316.05410767
2455287.6481599999	179063.8906	129867.7656	129867.7656	362.27322388	313.22018433	313.22018433
2455287.6489400002	179830.5156	127363.6797	127363.6797	363.64733887	310.04058838	310.04058838
2455287.6497000000	172277.0625	124484.5078	124484.5078	356.29385376	306.63653564	306.63653564
2455287.6504299999	174975.5469	130036.0703	130036.0703	359.35449219	313.17974854	313.17974854
2455287.6511800000	174102.2031	128156.9297	128156.9297	358.07067871	310.81549072	310.81549072
2455287.6519100000	176197.8438	127564.8516	127564.8516	359.84133911	311.38870239	311.38870239
2455287.6526700002	175360.7344	129503.0703	129503.0703	358.95852661	312.98022461	312.98022461

2455287.6534299999	175434.1250	120341.0469	120341.0469	360.21575928	302.64303589	302.64303589
2455287.6541700000	73743.0703	NaN	NaN	249.63183594	NaN	NaN
2455287.6549000000	159926.2812	114521.0625	114521.0625	345.60015869	297.09948730	297.09948730
2455287.6556600002	141571.2812	101827.2891	101827.2891	327.64776611	284.68280029	284.68280029
2455287.6563900001	126531.6250	95647.3672	95647.3672	312.05969238	278.21099854	278.21099854
2455287.6571499999	120019.6250	NaN	NaN	307.27987671	NaN	NaN
2455287.6578899999	129219.3047	87306.1172	87306.1172	316.31777954	267.52239990	267.52239990
2455287.6586600002	133342.8281	99357.1172	99357.1172	320.69171143	281.72128296	281.72128296
2455287.6594099998	140317.7031	102810.8438	102810.8438	327.38092041	285.46020508	285.46020508
2455287.6602400001	63329.5000	NaN	NaN	237.34680176	NaN	NaN
2455287.6609800002	137959.8125	100574.3984	100574.3984	323.56561279	282.84497070	282.84497070
2455287.6618499998	128967.4609	96691.3594	96691.3594	315.20785522	277.52679443	277.52679443
2455287.6625899998	152159.5312	112374.2344	112374.2344	339.16262817	296.05288696	296.05288696
2455287.6634499999	157576.0156	112923.9922	112923.9922	343.88958740	296.44470215	296.44470215
2455287.6641899999	146851.1406	105094.1484	105094.1484	332.87072754	287.71994019	287.71994019
2455287.6650299998	NaN	92499.3516	92499.3516	NaN	273.34838867	273.34838867
2455287.6657799999	129521.0000	94353.4297	94353.4297	316.61972046	275.35003662	275.35003662
2455287.6666199998	133632.1250	93154.0547	93154.0547	319.94467163	274.12942505	274.12942505
2455287.6673499998	149088.4531	NaN	NaN	335.42037964	NaN	NaN

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#GJD	target	reference1	reference2	error	ref.1err.	ref.2err.
2455293.6459700000	445230.7188	328635.6250	328635.6250	690.13702393	626.56628418	626.56628418
2455293.6467100000	383276.7188	281990.4375	281990.4375	668.47851562	606.79101562	606.79101562
2455293.6474799998	374949.7500	275903.6250	275903.6250	666.59008789	610.72784424	610.72784424
2455293.6482199999	371045.3750	273402.7188	273402.7188	665.78607178	615.75494385	615.75494385
2455293.6489700000	368001.9375	273575.2500	273575.2500	673.53607178	601.10144043	601.10144043
2455293.6497300002	370449.7812	273766.0938	273766.0938	672.40350342	605.87335205	605.87335205
2455293.6505100001	353143.5625	260980.1250	260980.1250	655.86425781	601.95654297	601.95654297
2455293.6512400000	390203.5625	289034.7500	289034.7500	674.18615723	610.36859131	610.36859131
2455293.6519800001	399056.3750	293668.8438	293668.8438	682.05957031	615.20440674	615.20440674
2455293.6527100001	433647.4688	321733.9375	321733.9375	685.11810303	624.05218506	624.05218506
2455293.6535100001	381606.9375	280923.2500	280923.2500	667.51525879	610.80053711	610.80053711
2455293.6542400001	331350.3125	246653.3594	246653.3594	643.99066162	597.07470703	597.07470703

2455293.6549800001	387641.0000	285563.0000	285563.0000	668.69763184	612.74932861	612.74932861
2455293.6557200002	361973.1250	268505.2812	268505.2812	662.84759521	598.92297363	598.92297363
2455293.6564799999	334118.3125	245556.7031	245556.7031	652.07507324	595.78295898	595.78295898
2455293.6572199999	345774.1562	254130.0156	254130.0156	654.32794189	592.46575928	592.46575928
2455293.6579499999	358109.7188	264576.1250	264576.1250	662.57928467	598.21484375	598.21484375
2455293.6586799999	401105.7188	297043.4062	297043.4062	676.47875977	616.33593750	616.33593750
2455293.6594900000	493992.6250	364980.5938	364980.5938	713.30535889	650.57794189	650.57794189
2455293.6602300000	415810.9375	306619.9375	306619.9375	681.02484131	613.45617676	613.45617676
2455293.6609999998	395253.3750	293278.8438	293278.8438	673.31597900	619.47174072	619.47174072
2455293.6617500000	405251.2812	297822.0938	297822.0938	677.68408203	619.14532471	619.14532471
2455293.6624799999	329621.3438	243698.8438	243698.8438	649.01733398	597.59655762	597.59655762
2455293.6631900002	363153.1250	266051.7812	266051.7812	654.56542969	609.44451904	609.44451904
2455293.6639500000	362811.0938	268931.9688	268931.9688	655.90350342	606.15399170	606.15399170
2455293.6646900000	346891.6250	254068.8125	254068.8125	653.82977295	598.85070801	598.85070801
2455293.6654200000	352500.9375	261922.9219	261922.9219	656.33740234	596.99243164	596.99243164
2455293.6661800002	360563.0312	267236.0625	267236.0625	662.08532715	603.95819092	603.95819092
2455293.6669200002	361428.4688	266377.5625	266377.5625	657.46704102	598.17425537	598.17425537
2455293.6676599998	358899.8438	264411.3750	264411.3750	665.97698975	604.31848145	604.31848145
2455293.6683899998	434699.2188	320188.2188	320188.2188	688.98919678	631.06036377	631.06036377
2455293.6691299998	412321.5000	300851.2812	300851.2812	678.32934570	619.52081299	619.52081299
2455293.6698599998	416391.8750	305713.8438	305713.8438	680.32678223	616.42218018	616.42218018
2455293.6706200000	478311.9375	353143.3438	353143.3438	707.10229492	638.71203613	638.71203613
2455293.6713899998	471247.1562	347102.0312	347102.0312	714.32574463	642.11700439	642.11700439
2455293.6721399999	500504.3438	367905.9062	367905.9062	716.97558594	646.65026855	646.65026855
2455293.6729199998	468095.1875	345000.2500	345000.2500	709.72180176	625.49084473	625.49084473
2455293.6736499998	355982.7812	257677.2031	257677.2031	667.62963867	592.55657959	592.55657959
2455293.6743899998	448192.0312	330708.7812	330708.7812	695.87231445	627.91992188	627.91992188
2455293.6751500000	430858.0312	317826.7812	317826.7812	686.96875000	626.66149902	626.66149902
2455293.6758900001	371183.7500	271383.1875	271383.1875	665.91406250	613.09051514	613.09051514
2455293.6767400000	457552.3125	335520.6250	335520.6250	699.57122803	630.96954346	630.96954346
2455293.6774800001	451829.1875	333564.5312	333564.5312	699.46423340	637.39514160	637.39514160
2455293.6782999998	340731.2812	249905.8750	249905.8750	651.47827148	598.18292236	598.18292236
2455293.6790300002	477779.7500	353776.3438	353776.3438	711.89331055	635.23638916	635.23638916
2455293.6798500000	511568.8125	376745.8125	376745.8125	723.37097168	648.20849609	648.20849609

2455293.6805900000	533291.8750	391860.0000	391860.0000	728.44360352	654.63348389	654.63348389
2455293.6813500002	495869.7188	364045.4062	364045.4062	713.10510254	643.39093018	643.39093018
2455293.6821499998	427148.5938	313118.3750	313118.3750	686.39141846	627.07293701	627.07293701
2455293.6828800002	462920.2188	339399.4062	339399.4062	700.14013672	634.19598389	634.19598389
2455293.6837300002	402010.7188	296909.4688	296909.4688	670.87683105	622.58764648	622.58764648
2455293.6844700002	373160.4688	274073.7500	274073.7500	664.82232666	607.25640869	607.25640869
2455293.6852199999	445794.6875	327681.2500	327681.2500	698.80590820	627.74371338	627.74371338
2455293.6859599999	450278.3125	331386.8750	331386.8750	703.19567871	637.21643066	637.21643066
2455293.6867499999	433825.0000	318943.9688	318943.9688	691.80639648	631.31134033	631.31134033
2455293.6874799998	417448.3125	307562.6875	307562.6875	685.40576172	621.12860107	621.12860107
2455293.6882500001	408500.8750	299558.8438	299558.8438	678.37042236	621.65936279	621.65936279
2455293.6889800001	386389.6250	281917.8438	281917.8438	668.74591064	610.32208252	610.32208252
2455293.6897800001	384223.2812	282946.8125	282946.8125	669.79479980	614.63092041	614.63092041
2455293.6905100001	343121.3750	252585.0625	252585.0625	651.79748535	595.10290527	595.10290527
2455293.6912600002	315324.0625	231727.2656	231727.2656	640.58905029	587.60101318	587.60101318
2455293.6919800001	308551.2188	226644.9375	226644.9375	637.27056885	585.70428467	585.70428467
2455293.6927100001	290690.0625	215424.2188	215424.2188	632.19097900	583.94219971	583.94219971
2455293.6934799999	227310.3281	168074.9844	168074.9844	600.82586670	568.35601807	568.35601807
2455293.6942099999	188476.7188	138142.0312	138142.0312	590.79162598	549.03198242	549.03198242
2455293.6949499999	181624.7656	132322.6406	132322.6406	582.54827881	564.69757080	564.69757080
2455293.6957100001	175308.3438	127751.3594	127751.3594	578.48834229	565.38092041	565.38092041
2455293.6964599998	134180.0625	97884.7812	97884.7812	567.07171631	539.77313232	539.77313232
2455293.6973100002	151276.7188	112055.7578	112055.7578	575.74383545	555.87689209	555.87689209
2455293.6980900001	165000.1406	121859.4297	121859.4297	586.17388916	553.30529785	553.30529785
2455293.6988200000	180351.2812	134152.8438	134152.8438	581.66339111	555.41052246	555.41052246
2455293.6995500000	212031.2344	156836.1719	156836.1719	598.58898926	567.36639404	567.36639404
2455293.7003000001	198980.1875	149220.4219	149220.4219	602.83282471	559.71508789	559.71508789
2455293.7010300001	223430.8125	165777.4531	165777.4531	602.11944580	566.74670410	566.74670410
2455293.7018700000	99.0000	99.0000	99.0000	602.11944580	566.74670410	566.74670410
2455293.7026700000	349978.7188	259879.5781	259879.5781	657.16534424	604.44519043	604.44519043
2455293.7034300002	327507.1250	239662.4531	239662.4531	644.88537598	594.53399658	594.53399658
2455293.7041799999	376378.0938	277675.8125	277675.8125	672.31378174	612.49273682	612.49273682
2455293.7049699998	411151.6875	301216.3750	301216.3750	676.21331787	614.85650635	614.85650635
2455293.7057200000	420344.4375	310249.5938	310249.5938	684.94445801	620.74597168	620.74597168

2455293.7064499999	408418.9688	299783.7500	299783.7500	678.90515137	621.30316162	621.30316162
2455293.7071799999	417990.9688	307997.8750	307997.8750	679.65179443	621.19708252	621.19708252
2455293.7079400001	284160.9688	NaN NaN	624.33959961	NaN NaN		
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2455293.7094800002	422481.2812	310561.7500	310561.7500	691.37683105	620.09515381	620.09515381
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2455293.7117699999	409820.7500	304153.7500	304153.7500	687.48248291	617.91821289	617.91821289
2455293.7125200001	419520.8750	309403.1250	309403.1250	691.75653076	621.61059570	621.61059570
2455293.7133399998	379779.1250	280020.9062	280020.9062	672.12133789	612.46600342	612.46600342
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2455293.7149200002	314732.4375	231257.4531	231257.4531	645.99523926	592.88427734	592.88427734
2455293.7156600002	315395.7500	229921.5625	229921.5625	636.55236816	586.08111572	586.08111572
2455293.7164799999	207511.2031	151365.5781	151365.5781	589.94189453	563.85662842	563.85662842
2455293.7172200000	262512.9688	196619.2969	196619.2969	612.99658203	571.46777344	571.46777344
2455293.7180300001	200265.9375	146840.8281	146840.8281	598.34472656	545.77734375	545.77734375
2455293.7188100000	186591.8125	134924.0781	134924.0781	582.71234131	542.00726318	542.00726318
2455293.7195400000	258078.9688	190323.7031	190323.7031	613.72552490	574.03698730	574.03698730
2455293.7203799998	315973.1562	234709.4844	234709.4844	640.01635742	593.16967773	593.16967773
2455293.7211099998	222309.8281	164418.0312	164418.0312	592.37463379	554.23553467	554.23553467
2455293.7219400001	483640.2188	355767.0625	355767.0625	713.14593506	645.88934326	645.88934326
2455293.7226999998	513374.4375	377418.3750	377418.3750	721.71551514	656.29791260	656.29791260
2455293.7234399999	518192.4375	378433.2500	378433.2500	727.55322266	654.37689209	654.37689209
2455293.7241699998	525947.4375	390028.8125	390028.8125	728.56457520	656.54162598	656.54162598
2455293.7250100002	307530.7812	238204.8438	238204.8438	643.94671631	591.59320068	591.59320068
2455293.7257400001	502258.4062	367250.4375	367250.4375	719.89599609	649.86981201	649.86981201
2455293.7265699999	512599.2188	375396.1250	375396.1250	726.93499756	660.09057617	660.09057617
2455293.7272999999	510267.4688	374795.7188	374795.7188	726.00097656	651.55541992	651.55541992
2455293.7281800001	505237.7812	370578.0000	370578.0000	720.31231689	653.77984619	653.77984619
2455293.7289700001	99.0000	99.0000	99.0000	720.31231689	653.77984619	653.77984619
2455293.7297600000	485813.6562	355660.2812	355660.2812	711.90179443	645.80310059	645.80310059
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2455293.7315900000	455420.8438	335571.5312	335571.5312	701.09674072	634.21502686	634.21502686
2455293.7323599998	469221.3438	346614.4688	346614.4688	707.53576660	645.16595459	645.16595459

2455293.7333399998	434180.6562	324867.2500	324867.2500	705.75604248	627.33850098	627.33850098
2455293.7341100001	437071.3125	318842.5625	318842.5625	694.51727295	630.81738281	630.81738281
2455293.7349500000	475533.1875	349404.5625	349404.5625	712.20190430	642.42034912	642.42034912
2455293.7358599999	486636.3750	362611.1562	362611.1562	711.72241211	649.00109863	649.00109863
2455293.7366300002	490508.1875	363011.8125	363011.8125	715.11145020	652.77014160	652.77014160
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2455293.7383400002	467425.2188	339038.2812	339038.2812	710.38262939	637.06042480	637.06042480
2455293.7390999999	468779.8438	343069.4375	343069.4375	711.68841553	638.92871094	638.92871094
2455293.7399499998	474501.0312	345459.6562	345459.6562	712.00164795	640.52301025	640.52301025
2455293.7406799998	480267.8438	352603.2812	352603.2812	713.08557129	646.81591797	646.81591797
2455293.7415399998	477481.2812	351124.9375	351124.9375	716.60546875	643.96081543	643.96081543
2455293.7422699998	488040.2188	358258.1250	358258.1250	709.10034180	647.20745850	647.20745850
2455293.7430400001	487695.3438	358618.7188	358618.7188	717.84832764	653.92492676	653.92492676
2455293.7437800001	471300.2812	347026.5938	347026.5938	714.54925537	647.69512939	647.69512939
2455293.7445299998	482781.2188	357701.7500	357701.7500	720.16180420	648.18237305	648.18237305

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#GJD	target	reference1	reference2	error	ref.1err.	ref.2err.
2455294.5365599999	516129.7812	385153.2812	385153.2812	741.17956543	666.19091797	666.19091797
2455294.5372600001	478134.3750	356206.5000	356206.5000	723.21691895	652.59661865	652.59661865
2455294.5380400000	363349.0625	268992.8438	268992.8438	686.06359863	625.47045898	625.47045898
2455294.5387499998	193999.7969	148860.5000	148860.5000	641.68890381	609.00231934	609.00231934
2455294.5395499999	28195.0312	20731.2578	20731.2578	666.63153076	632.35034180	632.35034180
2455294.5402500001	400689.2812	300490.7188	300490.7188	696.00665283	647.76544189	647.76544189
2455294.5410300000	487499.6875	365535.4062	365535.4062	733.29357910	661.34020996	661.34020996
2455294.5417399998	461102.7812	345966.6562	345966.6562	719.44195557	650.53802490	650.53802490
2455294.5425000000	351940.2500	268829.5312	268829.5312	675.34515381	619.72845459	619.72845459
2455294.5432099998	175413.6250	128664.6953	128664.6953	655.37615967	623.72290039	623.72290039
2455294.5439900002	313680.9375	233331.5312	233331.5312	665.47076416	633.32141113	633.32141113
2455294.5447000000	183585.7812	133306.5625	133306.5625	639.98864746	602.09381104	602.09381104
2455294.5454899999	157450.2031	118516.5703	118516.5703	626.87536621	609.54675293	609.54675293
2455294.5461800001	349705.3438	257945.7812	257945.7812	684.03759766	631.06823730	631.06823730
2455294.5469300002	578819.3750	432002.1250	432002.1250	758.19842529	686.61108398	686.61108398
2455294.5476199999	557106.5000	417194.9688	417194.9688	754.91967773	671.71997070	671.71997070

2455294.5483900001	482364.4688	357330.0000	357330.0000	716.97058105	645.45269775	645.45269775
2455294.5493200002	718835.2500	536226.9375	536226.9375	871.86444092	778.26635742	778.26635742
2455294.5501500000	793462.1875	592106.1875	592106.1875	894.36572266	808.56988525	808.56988525
2455294.5509600001	814218.4375	605773.6250	605773.6250	898.11260986	813.53454590	813.53454590
2455294.5518600000	809018.0625	601512.0625	601512.0625	901.97564697	810.32421875	810.32421875
2455294.5526700001	802469.7500	599184.6875	599184.6875	900.55584717	806.49645996	806.49645996
2455294.5535200001	813818.4375	605557.3125	605557.3125	899.29913330	809.57965088	809.57965088
2455294.5543300002	811140.1875	603104.0000	603104.0000	909.59082031	813.37731934	813.37731934
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2455294.5559700001	563428.3750	NaN	NaN	822.33837891	NaN	NaN
2455294.5568400002	608746.3750	456558.4062	456558.4062	834.39123535	755.66815186	755.66815186
2455294.5576599999	816859.1250	608883.6250	608883.6250	904.05664062	807.21502686	807.21502686
2455294.5608899998	462095.0312	349647.6875	349647.6875	799.91375732	746.68878174	746.68878174
2455294.5666100001	794970.0625	592651.8125	592651.8125	901.54125977	807.38043213	807.38043213
2455294.5674399999	794793.0625	595478.0000	595478.0000	894.56573486	806.92968750	806.92968750
2455294.5682999999	806560.4375	600786.0625	600786.0625	905.76538086	813.66479492	813.66479492
2455294.5718499999	785168.0625	586021.6875	586021.6875	888.61407471	807.04211426	807.04211426
2455294.5727100000	789815.5000	589715.0625	589715.0625	891.31909180	801.40533447	801.40533447
2455294.5736099998	774231.8125	578668.0625	578668.0625	885.02563477	807.27020264	807.27020264
2455294.5744800000	808601.6875	605395.8750	605395.8750	898.23590088	816.77258301	816.77258301
2455294.5753400000	814057.1250	607056.1875	607056.1875	899.52117920	812.49694824	812.49694824
2455294.5762000000	800392.6875	600571.6250	600571.6250	894.52832031	804.46789551	804.46789551
2455294.5770500000	816630.2500	613271.0625	613271.0625	903.42407227	813.27032471	813.27032471
2455294.5778899998	800953.7500	597824.4375	597824.4375	901.05828857	803.02539062	803.02539062
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2455294.5796200000	804884.5000	605153.1250	605153.1250	896.49896240	810.60314941	810.60314941
2455294.5805799998	802592.0000	600049.8750	600049.8750	893.52368164	807.06726074	807.06726074
2455294.5814200002	802858.1875	600411.1875	600411.1875	888.75115967	808.94964600	808.94964600
2455294.5822999999	802741.3125	599235.6875	599235.6875	892.03625488	805.32421875	805.32421875
2455294.5831599999	820476.6875	613865.6250	613865.6250	899.44915771	814.40917969	814.40917969
2455294.5840200000	818571.1250	613352.1875	613352.1875	900.11260986	811.09539795	811.09539795
2455294.5849400000	819555.1875	611807.8125	611807.8125	899.20013428	815.79528809	815.79528809
2455294.5858000000	819939.9375	611546.3125	611546.3125	892.60534668	811.30749512	811.30749512
2455294.5867400002	813716.4375	608854.6875	608854.6875	891.63690186	804.16290283	804.16290283

2455294.5875900001	816369.0625	610201.7500	610201.7500	899.55108643	807.51885986	807.51885986
2455294.5885000001	817758.6875	613196.1250	613196.1250	899.10974121	813.31561279	813.31561279
2455294.5893399999	814174.8125	608466.9375	608466.9375	898.28472900	810.68371582	810.68371582
2455294.5902499999	818934.0000	611399.3750	611399.3750	896.11724854	812.10253906	812.10253906
2455294.5911099999	813843.5625	611365.5625	611365.5625	891.55023193	813.64782715	813.64782715
2455294.5919800000	818550.3125	611606.2500	611606.2500	902.02526855	812.12475586	812.12475586
2455294.5928199999	824347.2500	614365.6250	614365.6250	898.75830078	803.47210693	803.47210693
2455294.5937700002	811155.4375	606858.5625	606858.5625	895.50726318	809.35369873	809.35369873
2455294.5946200001	825228.2500	615313.7500	615313.7500	900.61682129	806.51916504	806.51916504
2455294.5955699999	825167.2500	615408.0000	615408.0000	894.92816162	814.59661865	814.59661865
2455294.5964400000	822484.1250	614078.0000	614078.0000	906.62591553	809.69824219	809.69824219
2455294.5972799999	823663.6250	618374.1875	618374.1875	900.63659668	813.85980225	813.85980225
2455294.5981399999	828203.7500	619308.7500	619308.7500	900.47399902	816.41137695	816.41137695
2455294.5990599999	828533.5625	619623.8125	619623.8125	901.77117920	808.65637207	808.65637207
2455294.5999099999	NaN	NaN	NaN	NaN	NaN	NaN
2455294.6008400000	827775.6875	618675.0625	618675.0625	899.90484619	807.59014893	807.59014893
2455294.6017100001	826275.9375	614462.3750	614462.3750	897.58563232	802.73107910	802.73107910
2455294.6025800002	818164.1875	610483.3750	610483.3750	897.09069824	812.54406738	812.54406738
2455294.6035300000	802670.8750	602744.0625	602744.0625	893.25634766	804.04034424	804.04034424
2455294.6044100001	808298.6875	605022.6875	605022.6875	888.54754639	806.96899414	806.96899414
2455294.6053599999	816346.9375	607307.7500	607307.7500	896.06512451	802.51177979	802.51177979
2455294.6062400001	815958.1875	609761.4375	609761.4375	895.47802734	811.01507568	811.01507568
2455294.6071299999	822705.8750	613502.3125	613502.3125	893.46331787	804.28106689	804.28106689
2455294.6081099999	816669.1250	611296.2500	611296.2500	895.80853271	801.62695312	801.62695312
2455294.6089599999	822452.6250	614716.3750	614716.3750	897.64721680	809.92956543	809.92956543
2455294.6098799999	812244.0625	605934.5000	605934.5000	899.89703369	804.95745850	804.95745850
2455294.6107600001	813906.5000	608047.9375	608047.9375	895.50274658	804.75921631	804.75921631
2455294.6116200001	814390.1875	609700.1250	609700.1250	895.36450195	806.05157471	806.05157471
2455294.6125599998	800246.6250	597269.1250	597269.1250	892.66662598	809.82257080	809.82257080
2455294.6134100002	806945.3125	602321.9375	602321.9375	897.78149414	815.08374023	815.08374023
2455294.6142699998	813245.1250	603139.5625	603139.5625	897.05456543	808.71307373	808.71307373
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2455294.6160499998	813352.4375	608571.0625	608571.0625	892.65667725	810.85375977	810.85375977
2455294.6168999998	779712.8125	580180.0000	580180.0000	887.94354248	803.04345703	803.04345703

2455294.6177500002	801803.4375	603659.8125	603659.8125	897.01538086	807.29870605	807.29870605
2455294.6186299999	783082.0000	586662.5625	586662.5625	893.42559814	803.81878662	803.81878662
2455294.6194799999	779100.0625	583698.7500	583698.7500	889.34692383	809.06091309	809.06091309
2455294.6203399999	793596.9375	594689.8125	594689.8125	893.39886475	810.31890869	810.31890869
2455294.6212200001	786608.1875	588644.8750	588644.8750	897.22082520	805.76611328	805.76611328
2455294.6220900002	745854.8750	555810.3750	555810.3750	891.08740234	803.26794434	803.26794434
2455294.6229699999	793947.7500	593903.6875	593903.6875	894.33276367	803.32641602	803.32641602
2455294.6238199999	802388.6875	598856.8750	598856.8750	894.63928223	804.14270020	804.14270020
2455294.6246600002	802425.3750	597315.8750	597315.8750	893.03399658	810.73052979	810.73052979
2455294.6255100002	735071.5000	549964.2500	549964.2500	880.52191162	787.68499756	787.68499756
2455294.6263899999	747222.8125	557557.1875	557557.1875	880.11273193	802.65692139	802.65692139
2455294.6273400001	783526.5625	589602.8125	589602.8125	888.78723145	803.21612549	803.21612549
2455294.6284500002	787020.2500	588526.1875	588526.1875	891.11456299	803.57714844	803.57714844
2455294.6293199998	762462.3125	569031.4375	569031.4375	884.36059570	793.14019775	793.14019775
2455294.6302399999	588818.3125	438588.2812	438588.2812	824.20495605	753.16229248	753.16229248
2455294.6310999999	701535.1250	521623.5000	521623.5000	867.16265869	789.11822510	789.11822510
2455294.6321299998	740021.2500	552413.2500	552413.2500	874.64044189	794.16802979	794.16802979
2455294.6329899998	685156.3750	517483.5000	517483.5000	860.84143066	779.33642578	779.33642578
2455294.6338300002	784631.8125	586314.0625	586314.0625	896.74481201	803.71801758	803.71801758
2455294.6347200000	789932.2500	591224.7500	591224.7500	890.07861328	806.31024170	806.31024170
2455294.6355699999	788792.4375	588992.2500	588992.2500	889.45617676	811.67614746	811.67614746
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2455294.6373800002	769119.8125	575760.3125	575760.3125	887.09606934	803.44580078	803.44580078
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2455294.6391900000	762673.8125	568293.3125	568293.3125	894.06713867	808.46582031	808.46582031
2455294.6400500000	771839.6875	575300.0625	575300.0625	886.04254150	808.68133545	808.68133545
2455294.6408899999	775361.5000	579932.1250	579932.1250	889.25341797	801.13769531	801.13769531
2455294.6418099999	755632.0000	564722.0625	564722.0625	882.28363037	799.35388184	799.35388184
2455294.6426900001	791464.9375	590974.6250	590974.6250	891.34228516	807.79589844	807.79589844
2455294.6435300000	792106.8125	591413.5625	591413.5625	895.24627686	799.98608398	799.98608398
2455294.6443900000	784869.0000	586809.2500	586809.2500	891.19201660	807.64068604	807.64068604
2455294.6453100001	787173.8125	585866.8750	585866.8750	888.21673584	804.17547607	804.17547607
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2455294.6471500001	447643.2812	335548.8750	335548.8750	784.81213379	727.05151367	727.05151367

2455294.6480100001	780424.1875	579552.1875	579552.1875	894.80072021	804.92730713	804.92730713
2455294.6849900000	757683.8750	562962.1875	562962.1875	880.52471924	788.08746338	788.08746338
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2455294.6876500002	NaN	502215.5000	502215.5000	NaN	764.57318115	764.57318115
2455294.6885799998	752404.0625	559961.0000	559961.0000	875.13690186	788.95581055	788.95581055
2455294.6894200002	753682.5625	560939.7500	560939.7500	879.00531006	789.94213867	789.94213867
2455294.6903700000	NaN	NaN	NaN	NaN	NaN	NaN
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2455294.6931099999	757784.8125	557964.0000	557964.0000	878.72668457	782.92486572	782.92486572
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2455294.6959099998	732234.3125	549986.9375	549986.9375	871.36822510	776.56170654	776.56170654
2455294.6967600002	756071.6875	561359.1250	561359.1250	874.27478027	790.90466309	790.90466309
2455294.6976200002	755641.3125	561143.6250	561143.6250	878.37756348	790.62603760	790.62603760
2455294.6984999999	743294.8750	555913.7500	555913.7500	872.19641113	785.49426270	785.49426270
2455294.6993600000	753219.7500	560735.6875	560735.6875	874.46728516	801.34704590	801.34704590
2455294.7003600001	623207.6875	466179.3438	466179.3438	840.32531738	772.23907471	772.23907471
2455294.7012399998	747727.6250	558957.6250	558957.6250	874.39593506	795.42095947	795.42095947
2455294.7022600002	747815.6250	556424.6875	556424.6875	877.44140625	793.04266357	793.04266357
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2455294.7040400002	746056.9375	556468.3750	556468.3750	874.15502930	786.63238525	786.63238525
2455294.7048999998	745969.3125	555002.8125	555002.8125	875.48492432	786.88177490	786.88177490
2455294.7057500002	714571.2500	535141.3750	535141.3750	871.75482178	781.71118164	781.71118164
2455294.7066100002	726102.9375	541905.1875	541905.1875	862.20880127	788.28204346	788.28204346
2455294.7074699998	680041.2500	501574.1250	501574.1250	855.28674316	773.83972168	773.83972168

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#GJD	target	reference1	reference2	error	ref.1err.	ref.2err.
2455300.6015900001	469800.4375	349240.6875	349240.6875	617.57910156	542.44372559	542.44372559
2455300.6023700000	472249.1562	351761.5312	351761.5312	617.31475830	547.69073486	547.69073486
2455300.6031399998	469141.2812	349172.4688	349172.4688	617.22192383	544.96374512	544.96374512
2455300.6039600000	476695.6250	353799.7188	353799.7188	620.19329834	546.08380127	546.08380127

2455300.6050200001	628570.6875	468697.3750	468697.3750	712.16870117	626.73480225	626.73480225
2455300.6058999998	636587.6875	476093.0000	476093.0000	714.97235107	630.77081299	630.77081299
2455300.6067800000	632658.0625	470818.0625	470818.0625	714.68267822	628.93658447	628.93658447
2455300.6076600002	631913.8125	468496.5938	468496.5938	713.05395508	628.96411133	628.96411133
2455300.6085500000	630183.4375	468165.7188	468165.7188	711.93688965	628.64941406	628.64941406
2455300.6094999998	631924.1250	469143.4688	469143.4688	710.89910889	625.89916992	625.89916992
2455300.6104400000	631560.8750	471219.7812	471219.7812	711.20648193	626.55065918	626.55065918
2455300.6113800001	624234.7500	463653.9375	463653.9375	708.44519043	623.19860840	623.19860840
2455300.6122900001	632782.5000	469744.6875	469744.6875	710.83197021	628.38055420	628.38055420
2455300.6131500001	635279.1250	470597.8750	470597.8750	714.59417725	626.30712891	626.30712891
2455300.6140200002	633478.6875	469815.0312	469815.0312	712.14880371	626.98083496	626.98083496
2455300.6148799998	627895.4375	465896.4062	465896.4062	711.58557129	626.81140137	626.81140137
2455300.6157399998	631794.6250	469479.5625	469479.5625	711.68164062	627.87567139	627.87567139
2455300.6166300001	633124.0000	469752.1562	469752.1562	711.64788818	627.07141113	627.07141113
2455300.6175099998	630351.7500	470903.1250	470903.1250	711.22155762	631.63787842	631.63787842
2455300.6183799999	635027.0625	472012.2812	472012.2812	715.36914062	627.64190674	627.64190674
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2455300.6201300002	628033.4375	465831.6562	465831.6562	712.24212646	626.23461914	626.23461914
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2455300.6218900001	628093.1875	467274.8750	467274.8750	710.76611328	627.95794678	627.95794678
2455300.6227899999	573788.2500	424600.4375	424600.4375	691.62615967	611.24810791	611.24810791
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2455300.6247100001	622520.9375	465151.5000	465151.5000	704.80920410	627.55529785	627.55529785
2455300.6256499998	619639.3750	459057.9375	459057.9375	710.34063721	624.95129395	624.95129395
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2455300.6274799998	627919.0625	467218.0938	467218.0938	709.21624756	626.48242188	626.48242188
2455300.6283600000	627239.5000	466795.0312	466795.0312	709.72082520	628.42742920	628.42742920
2455300.6292099999	626703.0000	467599.4062	467599.4062	708.37182617	625.65386963	625.65386963
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2455300.6337500000	628396.4375	463419.5625	463419.5625	712.37030029	624.98876953	624.98876953
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2455300.6375299999	623045.9375	463141.4062	463141.4062	706.48999023	626.16400146	626.16400146
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2455300.6392700002	615973.1250	457671.7188	457671.7188	703.96948242	625.37133789	625.37133789
2455300.6401200001	620245.4375	461538.2188	461538.2188	704.59045410	625.03906250	625.03906250
2455300.6409999998	615853.1250	458372.2500	458372.2500	706.71215820	620.91125488	620.91125488
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2455300.6427699998	526217.0625	392773.6562	392773.6562	667.10479736	598.51177979	598.51177979
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2455300.6454500002	425669.9688	NaN	NaN	616.75439453	NaN	NaN
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2455300.6510899998	259806.1094	193027.0625	193027.0625	518.09216309	466.74966431	466.74966431
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2455300.6547200000	611811.5000	456646.1562	456646.1562	706.25244141	622.34820557	622.34820557
2455300.6555900001	616038.6875	455339.3750	455339.3750	705.58209229	624.43695068	624.43695068
2455300.6564400000	606973.6250	448683.4062	448683.4062	705.69714355	619.52178955	619.52178955
2455300.6572799999	615587.0625	457307.9688	457307.9688	709.26055908	625.98327637	625.98327637
2455300.6581899999	611036.2500	452565.8125	452565.8125	707.34832764	624.41137695	624.41137695
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2455300.6619600002	612278.5000	453328.9062	453328.9062	706.53466797	621.75714111	621.75714111
2455300.6629200000	598806.0625	445489.5938	445489.5938	699.35198975	618.19226074	618.19226074
2455300.6638900000	589309.8750	440649.4375	440649.4375	697.35083008	615.92272949	615.92272949
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2455300.6667200001	599561.6250	446095.7812	446095.7812	698.42480469	618.82482910	618.82482910
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2455300.6684500002	574245.8750	424121.1250	424121.1250	686.86340332	608.94927979	608.94927979
2455300.6693199999	596022.1250	444073.0938	444073.0938	697.29321289	614.86328125	614.86328125
2455300.6702100001	607044.1875	451091.6250	451091.6250	701.20794678	620.23815918	620.23815918
2455300.6711499998	581538.4375	431204.1562	431204.1562	693.85614014	609.94506836	609.94506836
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2455300.6729500000	598996.5625	445691.5000	445691.5000	699.49090576	615.79620361	615.79620361
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2455300.6814999999	595544.1875	437530.1875	437530.1875	697.92077637	612.89794922	612.89794922
2455300.6824300000	578966.8750	428658.9062	428658.9062	692.94720459	612.61718750	612.61718750
2455300.6833100002	594100.0000	443267.8438	443267.8438	693.36773682	620.55053711	620.55053711
2455300.6841699998	558128.6875	415291.5000	415291.5000	685.04644775	606.49859619	606.49859619
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2455300.6859400002	600324.7500	446231.2500	446231.2500	700.26141357	617.14837646	617.14837646
2455300.6869000001	604298.6875	447868.0312	447868.0312	699.54528809	621.76000977	621.76000977
2455300.6878900002	598867.0000	445665.4062	445665.4062	699.09857178	617.80023193	617.80023193
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2455300.6927700001	598533.0625	442313.9688	442313.9688	698.52960205	619.18572998	619.18572998
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2455300.7078499999	585347.5625	436846.1250	436846.1250	693.64770508	615.04357910	615.04357910
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2455301.5540900002	522980.7812	390196.0000	390196.0000	655.07440186	583.46142578	583.46142578
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2455301.6617100001	474900.0000	354036.8438	354036.8438	631.45922852	562.46118164	562.46118164
2455301.6624500002	486193.5000	363666.9375	363666.9375	638.64202881	571.40588379	571.40588379
2455301.6631800001	501350.4062	370142.5938	370142.5938	646.75134277	570.25250244	570.25250244
2455301.6639200002	503346.5312	375033.6250	375033.6250	647.51678467	575.24047852	575.24047852
2455301.6647800002	504669.4062	375067.1562	375067.1562	647.36596680	575.64801025	575.64801025
2455301.6655100002	292629.6250	NaN	NaN	532.31628418	NaN	NaN
2455301.6662400002	506119.6562	376471.1562	376471.1562	648.07427979	575.55798340	575.55798340
2455301.6669800002	509057.0938	379334.0625	379334.0625	649.35540771	579.53009033	579.53009033
2455301.6677199998	506710.4062	381117.1562	381117.1562	647.26501465	579.04272461	579.04272461
2455301.6685799998	508853.1250	379756.9688	379756.9688	649.42144775	576.42291260	576.42291260
2455301.6693199999	507125.4062	378594.9688	378594.9688	648.86456299	577.00146484	577.00146484
2455301.6700800001	510168.6562	381595.5938	381595.5938	648.72766113	577.51580811	577.51580811
2455301.6708300002	507225.4062	378167.9688	378167.9688	649.51586914	571.73101807	571.73101807
2455301.6715699998	497738.6250	374190.5000	374190.5000	643.90637207	573.35968018	573.35968018
2455301.6724000000	510639.0938	381315.1875	381315.1875	651.36450195	577.22406006	577.22406006
2455301.6732500000	510399.5625	380108.7812	380108.7812	651.53192139	576.70349121	576.70349121

2455301.6741700000	389334.5625	293164.9688	293164.9688	590.96008301	529.49462891	529.49462891
2455301.6750699999	506053.4375	377306.4062	377306.4062	648.68237305	577.00848389	577.00848389
2455301.6759100002	509117.5312	380101.1562	380101.1562	652.04290771	577.62200928	577.62200928
2455301.6767799999	316172.2812	237874.7344	237874.7344	551.17010498	498.49938965	498.49938965
2455301.6776399999	502656.0938	374216.5000	374216.5000	646.02478027	575.74224854	575.74224854
2455301.6785200001	501240.2188	373957.7500	373957.7500	645.16271973	575.71466064	575.71466064
2455301.6793900002	499095.1250	372167.0000	372167.0000	643.88250732	574.22167969	574.22167969
2455301.6802300001	503333.1875	377485.5000	377485.5000	648.71411133	577.41711426	577.41711426
2455301.6809700001	501448.6562	372320.4375	372320.4375	645.16400146	574.56774902	574.56774902
2455301.6817100001	504977.8750	375545.3125	375545.3125	645.67687988	577.07043457	577.07043457
2455301.6825100002	434575.1250	337399.3438	337399.3438	614.18621826	558.03808594	558.03808594
2455301.6832599998	502935.4688	376085.9375	376085.9375	647.71008301	577.63562012	577.63562012
2455301.6839899998	99.0000	99.0000	99.0000	647.71008301	577.63562012	577.63562012
2455301.6847500000	503181.2188	374778.4688	374778.4688	644.06756592	576.59863281	576.59863281
2455301.6855100002	500829.0000	375620.1562	375620.1562	645.27557373	575.91314697	575.91314697
2455301.6862400002	502474.2812	374433.7500	374433.7500	645.47222900	577.20800781	577.20800781
2455301.6869800002	498277.1562	371976.8125	371976.8125	644.68176270	575.28662109	575.28662109
2455301.6877100002	498943.0312	370644.3125	370644.3125	646.71734619	576.13476562	576.13476562
2455301.6884400002	501041.4375	372817.4062	372817.4062	645.48278809	575.87695312	575.87695312
2455301.6892900001	501043.3438	373085.7188	373085.7188	646.14276123	575.36993408	575.36993408
2455301.6901199999	504496.1875	375419.7188	375419.7188	649.62469482	575.43237305	575.43237305
2455301.6909400001	385113.0000	NaN	NaN	587.05877686	NaN	NaN
2455301.6917900001	494759.0938	371460.7188	371460.7188	646.81457520	577.48907471	577.48907471
2455301.6926199999	496823.3125	370457.7500	370457.7500	648.29876709	576.40240479	576.40240479
2455301.6934600002	459936.2188	340045.9062	340045.9062	626.38214111	562.24670410	562.24670410
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2455301.6949200002	496508.1875	369989.0938	369989.0938	644.59472656	575.74041748	575.74041748
2455301.6957600000	496794.1562	372842.7812	372842.7812	646.17047119	572.75750732	572.75750732
2455301.6966100000	493679.8750	368792.8750	368792.8750	646.18560791	576.75225830	576.75225830
2455301.6974700000	489729.0000	365273.0938	365273.0938	641.93884277	571.20727539	571.20727539
2455301.6983200000	473494.3750	354918.2500	354918.2500	632.96173096	566.24932861	566.24932861
2455301.6991599998	474367.5938	355327.1562	355327.1562	635.46319580	567.88244629	567.88244629
2455301.6999900001	476095.9062	358002.3438	358002.3438	639.39349365	570.02636719	570.02636719
2455301.7008600002	489246.8125	365789.8750	365789.8750	644.38299561	572.57598877	572.57598877

2455301.7015900002	485037.0938	364044.1875	364044.1875	640.72125244	573.46307373	573.46307373
2455301.7023399998	484890.6562	363147.5000	363147.5000	642.39923096	576.06127930	576.06127930
2455301.7031700001	488918.6875	363700.6875	363700.6875	645.93713379	576.06762695	576.06762695
2455301.7039600001	486812.6250	363182.3750	363182.3750	647.28424072	575.46435547	575.46435547
2455301.7047999999	418570.5938	310900.9688	310900.9688	609.63623047	551.87304688	551.87304688
2455301.7055400000	486486.1875	361949.4062	361949.4062	644.90380859	572.40020752	572.40020752
2455301.7062800000	487895.9375	362751.1562	362751.1562	647.26495361	574.31274414	574.31274414
2455301.7070100000	483491.8750	361135.2812	361135.2812	645.76391602	577.80554199	577.80554199
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2455301.7093600002	483046.0938	360160.2812	360160.2812	643.46575928	576.74725342	576.74725342
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2455301.7110799998	235434.7656	177112.6094	177112.6094	506.33599854	470.19876099	470.19876099
2455301.7119399998	480651.3750	359329.6875	359329.6875	642.01013184	575.79016113	575.79016113
2455301.7127800002	481061.6250	357646.7812	357646.7812	642.97277832	577.41876221	577.41876221
2455301.7136200001	473843.5625	353793.2188	353793.2188	642.57977295	575.71234131	575.71234131
2455301.7144300002	458313.6250	344166.8750	344166.8750	636.16644287	573.29351807	573.29351807
2455301.7152399998	474312.4375	354368.3750	354368.3750	643.09765625	572.95019531	572.95019531
2455301.7159699998	474734.7812	355543.0938	355543.0938	640.54785156	575.17834473	575.17834473
2455301.7167099998	463440.8125	344512.6875	344512.6875	637.50036621	566.87103271	566.87103271
2455301.7175799999	464674.0938	348457.4688	348457.4688	636.97454834	568.65020752	568.65020752
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2455301.7193300002	465001.4062	345342.0938	345342.0938	641.75592041	569.53784180	569.53784180
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2455301.7210800000	468600.5000	349850.2812	349850.2812	641.55859375	568.60113525	568.60113525
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2455301.7226300002	365545.4375	272884.5625	272884.5625	588.40539551	528.41009521	528.41009521
2455301.7233600002	459269.1875	342374.7188	342374.7188	635.69799805	566.37841797	566.37841797
2455301.7242500000	459597.5000	343693.9688	343693.9688	637.48419189	573.14483643	573.14483643
2455301.7249799999	457691.0938	339390.4062	339390.4062	632.44018555	566.63287354	566.63287354
2455301.7257099999	455994.6875	339604.8125	339604.8125	636.22644043	571.07501221	571.07501221
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2455301.7271900000	426360.1250	318356.5625	318356.5625	618.23107910	558.85211182	558.85211182
2455301.7280799998	358166.5312	268220.6562	268220.6562	587.94689941	532.13842773	532.13842773

2455301.7288199998	446640.0938	333241.6562	333241.6562	630.45361328	565.28991699	565.28991699
2455301.7295499998	436543.6562	323661.8750	323661.8750	623.86425781	563.36035156	563.36035156
2455301.7303599999	360129.5625	269057.4375	269057.4375	581.09014893	529.12750244	529.12750244
2455301.7312300000	216100.0938	164760.9375	164760.9375	503.43167114	466.56170654	466.56170654
2455301.7319899998	363853.0312	271520.8438	271520.8438	587.71392822	533.52740479	533.52740479
2455301.7327200002	308846.1250	228106.3750	228106.3750	558.53118896	507.61871338	507.61871338
2455301.7334599998	349268.9688	260646.3125	260646.3125	581.04064941	532.36132812	532.36132812
2455301.7342599998	368684.0625	274698.1562	274698.1562	596.98779297	539.39263916	539.39263916
2455301.7350300001	444872.3750	332347.1562	332347.1562	634.87707520	568.85162354	568.85162354
2455301.7357500000	400210.3438	299876.7500	299876.7500	609.13427734	549.77398682	549.77398682
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2455301.7374900002	392987.0312	296815.3125	296815.3125	605.23712158	543.87799072	543.87799072
2455301.7382299998	388428.4062	289208.4375	289208.4375	600.91162109	540.88598633	540.88598633
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2455301.7400300000	404314.0312	301160.7500	301160.7500	613.65716553	549.20776367	549.20776367
2455301.7408799999	387082.6875	290061.4062	290061.4062	603.06726074	545.11352539	545.11352539
2455301.7417600001	363486.3438	273113.2500	273113.2500	589.11199951	534.86181641	534.86181641
2455301.7426000000	NaN NaN NaN	NaN NaN NaN				
2455301.7433300000	391810.6562	291752.3438	291752.3438	604.52825928	549.58673096	549.58673096
2455301.7440700000	370908.3438	278897.8125	278897.8125	596.47631836	536.76141357	536.76141357
2455301.7450000001	380140.5625	285672.3438	285672.3438	602.71832275	545.52307129	545.52307129
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2455301.7474400001	393202.8438	294666.1875	294666.1875	608.12506104	545.89367676	545.89367676
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2455301.7491400000	388446.2188	290614.1875	290614.1875	607.36090088	550.62402344	550.62402344
2455301.7499699998	390763.6562	291255.9375	291255.9375	607.58410645	547.41284180	547.41284180
2455301.7508200002	374549.5000	279995.7188	279995.7188	604.92987061	541.78546143	541.78546143
2455301.7516200002	425295.5312	317615.1562	317615.1562	626.88824463	562.67913818	562.67913818
2455301.7523699999	429109.8750	320097.7812	320097.7812	627.79187012	565.54974365	565.54974365
2455301.7532299999	414574.5312	308055.2812	308055.2812	619.30792236	561.96063232	561.96063232
2455301.7539900001	385998.8750	286697.4688	286697.4688	603.89416504	550.10046387	550.10046387
2455301.7547300002	368140.5312	271575.2188	271575.2188	593.26239014	540.86840820	540.86840820
2455301.7557999999	358352.6562	268574.6562	268574.6562	591.51434326	543.38934326	543.38934326

2455301.7566100000	373083.9688	277672.6250	277672.6250	599.85589600	543.32415771	543.32415771
2455301.7573699998	374427.2812	278231.6562	278231.6562	602.75238037	544.72003174	544.72003174
2455301.7582200002	325719.4375	242182.7812	242182.7812	584.35339355	527.56848145	527.56848145
2455301.7590600001	357661.9375	267903.4688	267903.4688	594.38964844	538.22784424	538.22784424
2455301.7661700002	364759.1562	272095.6250	272095.6250	601.38543701	544.06390381	544.06390381
2455301.7669099998	343973.2188	255200.4375	255200.4375	591.80377197	534.76800537	534.76800537
2455301.7677400000	357110.0312	263825.9062	263825.9062	591.78027344	532.47235107	532.47235107
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2455301.7723800000	380718.6562	282827.5000	282827.5000	609.73382568	550.48181152	550.48181152
2455301.7731699999	371097.0312	276585.1250	276585.1250	604.40045166	548.78076172	548.78076172
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2455301.7747800001	369830.5312	275749.4062	275749.4062	608.30169678	548.91558838	548.91558838
2455301.7756500002	375140.5938	278716.5312	278716.5312	607.59094238	552.41949463	552.41949463
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2455301.7779299999	380709.2500	280068.2500	280068.2500	615.50073242	554.90399170	554.90399170
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2455301.7802200001	377300.5938	279386.0938	279386.0938	612.84948730	555.83587646	555.83587646
2455301.7809400000	378981.3438	281467.6562	281467.6562	614.41168213	554.14044189	554.14044189
2455301.7817099998	380471.5000	282554.9062	282554.9062	617.40686035	553.90802002	553.90802002
2455301.7825900000	356792.5625	264311.0625	264311.0625	605.67633057	544.99243164	544.99243164
2455301.7834100001	375552.5625	280540.4062	280540.4062	611.92315674	560.73583984	560.73583984
2455301.7842399999	374177.3125	277176.0000	277176.0000	613.65856934	559.86206055	559.86206055
2455301.7849800000	367515.7188	271295.5000	271295.5000	611.52606201	553.74407959	553.74407959
2455301.7857100000	345620.0312	256983.1875	256983.1875	600.21887207	545.95611572	545.95611572
2455301.7864600001	341291.3438	252898.1250	252898.1250	594.07348633	542.60943604	542.60943604
2455301.7872100002	351190.0312	264188.3438	264188.3438	601.76898193	552.96032715	552.96032715
2455301.7879300001	353553.7188	261636.5625	261636.5625	601.67712402	547.56909180	547.56909180
2455301.7887300001	343106.8750	254671.9375	254671.9375	596.23144531	542.37481689	542.37481689
2455301.7895599999	364111.7188	270231.6562	270231.6562	607.29614258	549.59985352	549.59985352

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2455301.7911600000	96726.0703	71873.2031	71873.2031	448.51538086	434.53231812	434.53231812
2455301.7919399999	366746.6875	271991.6562	271991.6562	613.63476562	551.95739746	551.95739746
2455301.7926699999	361393.1562	268001.1562	268001.1562	604.30596924	554.29425049	554.29425049
2455301.7934300001	352158.3438	261186.3750	261186.3750	599.87249756	549.66375732	549.66375732
2455301.7942499998	357682.3750	264300.6250	264300.6250	605.67517090	552.19769287	552.19769287
2455301.7950200001	358769.4062	266524.1250	266524.1250	606.07873535	553.97979736	553.97979736
2455301.7958800001	363636.3438	270387.3125	270387.3125	608.66217041	557.68359375	557.68359375
2455301.7967200000	363150.6250	268937.0000	268937.0000	612.05792236	548.84643555	548.84643555
2455301.7974500000	364632.0312	270313.4688	270313.4688	611.23217773	556.93267822	556.93267822
2455301.7982100002	363270.0625	270051.1250	270051.1250	608.38055420	553.32849121	553.32849121
2455301.7989500002	358131.6250	264108.7812	264108.7812	604.75775146	550.80560303	550.80560303
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2455301.8013300002	351853.6562	261535.2812	261535.2812	604.26049805	550.69598389	550.69598389
2455301.8020600001	354157.2188	262159.6562	262159.6562	610.08978271	544.55383301	544.55383301
2455301.8027900001	353718.3438	262462.6875	262462.6875	606.55426025	549.50482178	549.50482178
2455301.8035200001	352940.5312	261757.0469	261757.0469	601.56127930	553.06292725	553.06292725
2455301.8043100000	352112.0312	260842.7812	260842.7812	605.75567627	553.07446289	553.07446289
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2455301.8060300001	347190.7500	256136.0938	256136.0938	601.84991455	548.48278809	548.48278809
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2455301.8091199999	345844.6562	257339.0469	257339.0469	600.20916748	552.29290771	552.29290771
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2455301.8129599998	336596.8125	251063.6719	251063.6719	592.90710449	543.29968262	543.29968262
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2455301.8211699999	301373.1250	224419.6875	224419.6875	582.10046387	532.52728271	532.52728271
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2455305.7670800001	162483.0469	119750.7891	119750.7891	354.85253906	312.68341064	312.68341064
2455305.7679300001	160994.9531	119358.5547	119358.5547	354.97439575	310.14807129	310.14807129
2455305.7687599999	89033.4531	NaN	NaN	279.09649658	NaN	NaN
2455305.7696099998	159715.7344	119204.6562	119204.6562	352.34286499	312.10256958	312.10256958
2455305.7704500002	159812.7344	118829.1250	118829.1250	351.54504395	309.88916016	309.88916016
2455305.7713199998	156181.4375	115125.3438	115125.3438	348.88113403	306.95407104	306.95407104
2455305.7721600002	159048.3594	118075.1406	118075.1406	351.84408569	309.15313721	309.15313721
2455305.7730100001	157431.3750	116414.3125	116414.3125	351.43209839	308.11871338	308.11871338
2455305.7738500000	156600.7344	116558.6250	116558.6250	349.40692139	308.28256226	308.28256226
2455305.7747100000	152972.6562	114007.6172	114007.6172	347.85833740	305.61132812	305.61132812
2455305.7755999998	156431.5938	114806.9453	114806.9453	350.74188232	305.57501221	305.57501221
2455305.7764499998	156532.8594	115230.6094	115230.6094	350.70281982	307.70037842	307.70037842
2455305.7772900001	NaN	104819.1406	104819.1406	NaN	295.79431152	295.79431152
2455305.7781400001	154932.5156	115324.8047	115324.8047	348.42016602	307.31466675	307.31466675
2455305.7789799999	152163.2500	112226.9688	112226.9688	345.61010742	303.96920776	303.96920776
2455305.7799100000	140454.6250	100237.6250	100237.6250	335.81063843	290.07653809	290.07653809

2455305.7807499999	145157.8125	107961.4688	107961.4688	340.24414062	300.13552856	300.13552856
2455305.7815999999	149088.1094	109669.5938	109669.5938	343.54562378	301.47589111	301.47589111
2455305.7824300001	146026.1875	109060.5547	109060.5547	341.44061279	300.97952271	300.97952271
2455305.7832800001	143899.7969	105675.7031	105675.7031	338.66793823	298.27297974	298.27297974
2455305.7842100002	144596.8281	107474.8750	107474.8750	340.22473145	298.87145996	298.87145996
2455305.7850600001	144915.2969	107113.1641	107113.1641	339.49298096	299.97949219	299.97949219
2455305.7858899999	55986.1953	NaN	NaN	241.52427673	NaN	NaN
2455305.7867500000	142952.8281	106139.6875	106139.6875	338.64328003	299.00878906	299.00878906
2455305.7875899998	142744.6562	105903.2266	105903.2266	337.51242065	297.34588623	297.34588623
2455305.7885199999	129835.2578	94054.8984	94054.8984	325.47363281	286.17324829	286.17324829
2455305.7893800000	140927.2812	104222.9766	104222.9766	337.61190796	297.45394897	297.45394897
2455305.7902199998	140949.9062	103914.0078	103914.0078	338.26852417	298.00314331	298.00314331
2455305.7910500001	139699.7656	104524.8984	104524.8984	335.50070190	296.83004761	296.83004761
2455305.7919100001	139470.6875	102123.2734	102123.2734	335.91296387	294.45010376	294.45010376
2455305.7928100000	137507.9844	101314.7344	101314.7344	334.24978638	293.80783081	293.80783081
2455305.7936600000	136827.6875	100055.0938	100055.0938	333.17028809	291.63827515	291.63827515
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2455305.7954299999	133710.0312	97836.7188	97836.7188	331.00366211	291.11749268	291.11749268
2455305.7962699998	132694.4531	97392.8672	97392.8672	328.66656494	290.42800903	290.42800903
2455305.7971299998	99609.1562	NaN	NaN	296.24826050	NaN	NaN
2455305.7979700002	129639.8594	96767.2344	96767.2344	326.46166992	289.53674316	289.53674316
2455305.7988200001	123288.0703	91614.8984	91614.8984	320.95864868	283.01406860	283.01406860
2455305.7996800002	128653.9453	94063.3359	94063.3359	325.30685425	286.42160034	286.42160034
2455305.8005100000	126748.8984	95102.7812	95102.7812	323.48522949	287.87179565	287.87179565
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2455305.8021999998	126725.9453	94243.4297	94243.4297	323.52536011	287.82110596	287.82110596
2455305.8030400001	119608.2266	89587.8281	89587.8281	317.14550781	282.95339966	282.95339966
2455305.8039699998	125791.0859	93602.5781	93602.5781	322.37500000	287.72283936	287.72283936
2455305.8048100001	124782.3984	91932.3438	91932.3438	321.64028931	283.81088257	283.81088257
2455305.8056600001	99.0000	99.0000	99.0000	321.64028931	283.81088257	283.81088257
2455305.8064999999	121038.6250	90104.3906	90104.3906	318.56829834	282.26190186	282.26190186
2455305.8073700001	120734.7266	88435.5234	88435.5234	317.80520630	279.21856689	279.21856689
2455305.8082200000	121105.1016	89020.0078	89020.0078	318.23040771	281.75689697	281.75689697
2455305.8090599999	117582.1719	88647.8516	88647.8516	314.54180908	280.23083496	280.23083496

2455305.8099199999	120723.3203	88827.7109	88827.7109	318.16018677	280.92211914	280.92211914
2455305.8107599998	120779.9453	89295.9062	89295.9062	318.73767090	281.28625488	281.28625488
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2455305.8133800002	114730.8906	85431.0469	85431.0469	311.70938110	278.68051147	278.68051147
2455305.8142400002	79909.4688	NaN	NaN	274.22302246	NaN	NaN
2455305.8151199999	63853.7617	55251.6328	55251.6328	254.41592407	242.87458801	242.87458801
2455305.8159800000	110541.3594	83159.8438	83159.8438	306.14916992	273.30740356	273.30740356
2455305.8169399998	110799.3828	83406.3281	83406.3281	307.81060791	274.99029541	274.99029541
2455305.8178099999	110957.9766	80353.7578	80353.7578	307.69033813	270.90756226	270.90756226
2455305.8186800000	110598.6328	80370.0391	80370.0391	308.24642944	270.10076904	270.10076904
2455305.8195600002	107270.5312	80435.7188	80435.7188	303.71853638	270.72103882	270.72103882
2455305.8204299998	106325.4844	78979.7734	78979.7734	303.14987183	270.08676147	270.08676147
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2455305.8222099999	104160.0938	76808.7734	76808.7734	300.28237915	265.71533203	265.71533203
2455305.8230599998	71280.7734	NaN	NaN	265.32196045	NaN	NaN
2455305.8239199999	89467.2031	67947.3047	67947.3047	286.52191162	257.74609375	257.74609375
2455305.8247799999	102300.1797	74648.6875	74648.6875	298.12857056	263.90921021	263.90921021
2455305.8256399999	100811.6953	74227.7734	74227.7734	298.57620239	265.33032227	265.33032227
2455305.8265999998	100796.1797	73220.2812	73220.2812	298.20175171	263.06863403	263.06863403
2455305.8274500002	99063.8906	72752.4766	72752.4766	295.93002319	263.56503296	263.56503296
2455305.8283099998	96956.4219	71234.0078	71234.0078	293.77023315	259.76559448	259.76559448
2455305.8291600002	95654.2656	70949.2188	70949.2188	291.01199341	260.97814941	260.97814941
2455305.8300100002	72764.4688	53285.0508	53285.0508	267.08840942	238.95288086	238.95288086
2455305.8309399998	88810.9844	NaN	NaN	284.00320435	NaN	NaN
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2455305.8336200002	92502.5625	70036.9766	70036.9766	287.73831177	258.82147217	258.82147217
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2455305.8362599998	89209.7344	65795.9766	65795.9766	283.23895264	255.17259216	255.17259216
2455305.8371600001	86070.0859	63861.8477	63861.8477	281.30734253	251.42620850	251.42620850
2455305.8380600000	86594.8516	64832.1992	64832.1992	281.04003906	255.00613403	255.00613403
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2455305.8414799999	84079.7578	62348.4688	62348.4688	277.54110718	250.50688171	250.50688171
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2455305.8440500000	80299.2500	60809.1367	60809.1367	274.85723877	251.40863037	251.40863037
2455305.8448800002	81930.7031	59332.7617	59332.7617	277.62847900	248.11813354	248.11813354
2455305.8457399998	80366.0391	58758.2734	58758.2734	275.39965820	248.21795654	248.21795654
2455305.8466599998	76757.5078	57780.5586	57780.5586	272.02035522	244.45433044	244.45433044
2455305.8475000001	77023.3828	56773.9883	56773.9883	272.44403076	243.73364258	243.73364258
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2455305.8492700001	-331.5470	NaN	NaN	158.40034485	NaN	NaN
2455305.8501200001	156.2572	247.3255	247.3255	158.14974976	167.65960693	167.65960693
2455305.8510099999	71762.5156	53590.8633	53590.8633	267.03143311	245.01289368	245.01289368
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2455305.8527400000	NaN	51579.1523	51579.1523	NaN	241.07975769	241.07975769
2455305.8535900000	69956.0000	50510.4648	50510.4648	263.98294067	237.46838379	237.46838379
2455305.8545300001	67094.4062	51695.6797	51695.6797	261.61279297	239.50346375	239.50346375
2455305.8553700000	178.6452	181.2857	181.2857	155.56900024	165.37690735	165.37690735
2455305.8562200000	69942.2031	50699.2461	50699.2461	264.41952515	239.04745483	239.04745483
2455305.8571100002	-114.1304	3416.5618	3416.5618	157.96241760	177.98539734	177.98539734
2455305.8579500001	NaN	48862.5430	48862.5430	NaN	237.19165039	237.19165039
2455305.8588200002	61976.1172	48744.0469	48744.0469	254.02044678	236.82356262	236.82356262
2455305.8597100000	63913.0742	47660.8711	47660.8711	258.08456421	233.15341187	233.15341187
2455305.8605399998	64347.0156	45623.1953	45623.1953	259.33041382	231.26455688	231.26455688
2455305.8614099999	99.0000	99.0000	99.0000	259.33041382	231.26455688	231.26455688
2455305.8622699999	61456.8008	44540.3828	44540.3828	252.97985840	228.23573303	228.23573303
2455305.8631099998	-204.3657	-102.0350	-102.0350	155.41912842	164.36656189	164.36656189
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2455305.8657200001	NaN	40667.7383	40667.7383	NaN	224.06697083	224.06697083
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2455305.8675000002	53682.8633	39708.6758	39708.6758	247.72041321	224.90423584	224.90423584
2455305.8684999999	51479.5977	36634.7070	36634.7070	241.01126099	218.17738342	218.17738342

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2455305.8711199998	NaN	35701.2734	35701.2734	NaN	217.81520081	217.81520081	
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2455305.8729200000	NaN	19828.7539	19828.7539	NaN	201.35014343	201.35014343	
2455305.8737699999	NaN	33375.8203	33375.8203	NaN	213.37168884	213.37168884	
2455305.8746600002	NaN	33272.0273	33272.0273	NaN	215.91868591	215.91868591	
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2455305.8817500002	NaN	26397.9062	26397.9062	NaN	203.55047607	203.55047607	
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2455305.8923999998	99.0000	99.0000	99.0000	326.45578003	326.30035400	326.30035400	
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2455305.8941000002	99.0000	99.0000	99.0000	326.45578003	326.30035400	326.30035400	
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2455305.9021200002	99.0000	99.0000	99.0000	NaN	NaN	NaN
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2455305.9164499999	99.0000	99.0000	99.0000	NaN	NaN	NaN
2455305.9172999999	169.4649	910.7153	910.7153	580.06207275	574.48779297	574.48779297
2455305.9181700000	1010.8359	-1092.2202	-1092.2202	663.20538330	651.52764893	651.52764893
2455305.9190300000	99.0000	99.0000	99.0000	663.20538330	651.52764893	651.52764893
2455305.9199799998	99.0000	99.0000	99.0000	663.20538330	651.52764893	651.52764893
2455305.9208200001	99.0000	99.0000	99.0000	663.20538330	651.52764893	651.52764893

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#GJD	target	reference1	reference2	error	ref.1err.	ref.2err.
2455309.5456800000	445703.0000	334146.4062	334146.4062	643.00476074	575.83044434	575.83044434
2455309.5465299999	446386.4062	331570.3125	331570.3125	640.62780762	579.88012695	579.88012695
2455309.5472599999	446535.1250	334105.8438	334105.8438	640.18542480	582.01965332	582.01965332
2455309.5480399998	446765.3438	332410.3438	332410.3438	641.41003418	577.30786133	577.30786133
2455309.5488200001	447997.6250	333879.3125	333879.3125	643.20532227	574.57952881	574.57952881
2455309.5495500001	452184.6562	336028.1875	336028.1875	640.57189941	577.14752197	577.14752197

2455309.5502999998	450915.7500	334237.6250	334237.6250	640.29577637	572.64898682	572.64898682
2455309.5510300002	450420.7812	334534.9688	334534.9688	642.91125488	568.23291016	568.23291016
2455309.5517799999	450201.3750	336386.8438	336386.8438	640.45324707	576.81494141	576.81494141
2455309.5525500001	448558.9688	336662.2500	336662.2500	638.85552979	573.21734619	573.21734619
2455309.5532900002	447414.2500	333060.7812	333060.7812	635.66906738	571.99450684	571.99450684
2455309.5540399998	447896.5000	334224.2188	334224.2188	641.21142578	572.33056641	572.33056641
2455309.5547799999	448286.7188	334698.5625	334698.5625	638.86987305	575.87847900	575.87847900
2455309.5555300000	447240.0312	334359.6562	334359.6562	634.16656494	574.51336670	574.51336670
2455309.5562999998	449408.0312	333982.1562	333982.1562	636.14880371	574.86962891	574.86962891
2455309.5570499999	447803.1250	333949.0938	333949.0938	637.78063965	577.31842041	577.31842041
2455309.5577799999	446461.7500	333282.4688	333282.4688	635.87908936	572.33349609	572.33349609
2455309.5585200000	446197.4688	331907.5312	331907.5312	639.06671143	574.18292236	574.18292236
2455309.5592899998	447586.5625	332791.5000	332791.5000	637.69915771	575.38012695	575.38012695
2455309.5600700001	446236.2812	333087.9375	333087.9375	634.48645020	574.13610840	574.13610840
2455309.5608000001	439368.2500	328156.4062	328156.4062	634.23150635	572.30499268	572.30499268
2455309.5615599998	445499.0312	332121.6562	332121.6562	638.00439453	572.17266846	572.17266846
2455309.5624099998	445294.8750	331706.2812	331706.2812	636.70892334	568.93542480	568.93542480
2455309.5631499998	443905.0625	331102.3438	331102.3438	637.75732422	574.19873047	574.19873047
2455309.5639800001	444857.8125	330056.7812	330056.7812	634.86535645	571.45825195	571.45825195
2455309.5647200001	445197.5938	331365.8750	331365.8750	634.35949707	568.67059326	568.67059326
2455309.5654600002	442994.0625	330167.8750	330167.8750	636.82940674	572.62249756	572.62249756
2455309.5662300000	434963.2812	323902.6250	323902.6250	633.23760986	567.99865723	567.99865723
2455309.5669800001	440652.7188	327687.9375	327687.9375	641.22149658	572.60955811	572.60955811
2455309.5677399999	439070.1250	327010.3438	327010.3438	633.75305176	571.93292236	571.93292236
2455309.5685100001	438691.2500	326878.2812	326878.2812	635.50872803	565.98840332	565.98840332
2455309.5692599998	439967.6875	327831.2188	327831.2188	634.90417480	571.65087891	571.65087891
2455309.5700200000	440873.6562	328316.0000	328316.0000	636.52581787	570.33618164	570.33618164
2455309.5707600000	440042.6875	328203.1562	328203.1562	637.32922363	572.67651367	572.67651367
2455309.5715299998	439630.3750	327145.9375	327145.9375	638.36340332	568.79095459	568.79095459
2455309.5722800000	440604.7188	327976.8125	327976.8125	634.99218750	570.18243408	570.18243408
2455309.5730400002	438107.9688	326806.4688	326806.4688	632.53503418	568.98242188	568.98242188
2455309.5737800002	441792.2500	328162.3438	328162.3438	638.07000732	569.58544922	569.58544922
2455309.5745899999	441395.6875	327136.2188	327136.2188	636.87164307	570.15246582	570.15246582
2455309.5753700002	442604.3438	328721.6250	328721.6250	636.39703369	568.02734375	568.02734375

2455309.5761799999	438775.2500	326979.0000	326979.0000	634.37268066	572.61077881	572.61077881
2455309.5769099998	437584.9688	324515.8438	324515.8438	634.37426758	566.25964355	566.25964355
2455309.5776600000	439229.9062	327284.2500	327284.2500	636.96771240	573.09765625	573.09765625
2455309.5784800001	442349.7812	327723.6562	327723.6562	636.40087891	571.63031006	571.63031006
2455309.5792100001	439176.6562	326536.4688	326536.4688	637.66943359	568.78607178	568.78607178
2455309.5799799999	404304.0625	300345.0938	300345.0938	630.33001709	556.20074463	556.20074463
2455309.5806900002	428195.6250	318176.9062	318176.9062	625.53259277	563.95056152	563.95056152
2455309.5814600000	438911.1250	326308.7812	326308.7812	636.52496338	566.23645020	566.23645020
2455309.5822100001	438313.9062	326471.1250	326471.1250	628.09533691	565.20947266	565.20947266
2455309.5829300000	437102.8750	323168.1250	323168.1250	633.91741943	563.84338379	563.84338379
2455309.5836900002	439662.5312	326982.2812	326982.2812	632.52319336	563.46051025	563.46051025
2455309.5845300001	439110.5000	327079.7812	327079.7812	633.48339844	568.59655762	568.59655762
2455309.5852800002	440992.1562	328006.4375	328006.4375	632.60998535	568.21661377	568.21661377
2455309.5860600001	441158.0625	327597.9375	327597.9375	632.02795410	573.06951904	573.06951904
2455309.5868299999	440918.0938	329254.3125	329254.3125	633.27734375	571.36456299	571.36456299
2455309.5876500001	440435.4062	327624.4688	327624.4688	630.15716553	567.33435059	567.33435059
2455309.5883999998	441443.8438	327631.1875	327631.1875	636.12884521	570.09515381	570.09515381
2455309.5891700001	436792.2188	325525.5312	325525.5312	634.70556641	569.76043701	569.76043701
2455309.5899499999	441651.5625	327145.0312	327145.0312	630.06164551	568.03222656	568.03222656
2455309.5907100001	437488.5312	324136.9375	324136.9375	633.64697266	566.72021484	566.72021484
2455309.5914500002	438760.5312	326012.9688	326012.9688	635.02026367	568.77075195	568.77075195
2455309.5921999998	439092.9688	326774.9688	326774.9688	634.63842773	571.26843262	571.26843262
2455309.5929399999	434455.1875	321740.2812	321740.2812	632.99426270	568.00286865	568.00286865
2455309.5936900000	438895.3750	326485.2812	326485.2812	633.03063965	570.14038086	570.14038086
2455309.5944300001	440182.8438	325275.5625	325275.5625	632.21276855	567.08471680	567.08471680
2455309.5951700001	441832.2812	326701.4375	326701.4375	635.52661133	566.86175537	566.86175537
2455309.5959299998	440381.5312	330254.2812	330254.2812	633.35327148	567.57373047	567.57373047
2455309.5966900000	444225.4375	330527.3750	330527.3750	636.95916748	567.97845459	567.97845459
2455309.5974400002	445622.6875	331269.3750	331269.3750	633.65356445	577.48828125	577.48828125
2455309.5981800002	446604.6250	330429.0312	330429.0312	631.33886719	567.02606201	567.02606201
2455309.5989100002	442554.3750	327190.4375	327190.4375	631.54876709	568.18164062	568.18164062
2455309.5996800000	440280.7188	328101.8438	328101.8438	634.63726807	564.26464844	564.26464844
2455309.6004200000	444567.5938	331819.1875	331819.1875	635.65405273	561.96960449	561.96960449
2455309.6012700000	447508.8125	332537.2500	332537.2500	634.72442627	568.48547363	568.48547363

2455309.6020300002	446737.0312	332222.4688	332222.4688	635.42919922	568.38903809	568.38903809
2455309.6028800001	447692.8125	332457.8125	332457.8125	637.72113037	568.13464355	568.13464355
2455309.6036299998	446387.5312	331123.7500	331123.7500	633.16809082	571.99871826	571.99871826
2455309.6044700001	445399.7500	331186.6875	331186.6875	636.56750488	567.71148682	567.71148682
2455309.6052299999	446215.8438	330836.6562	330836.6562	637.40283203	565.25701904	565.25701904
2455309.6059800000	449122.0938	332993.2500	332993.2500	633.76135254	565.63305664	565.63305664
2455309.6067400002	446680.0938	332267.6250	332267.6250	634.11773682	573.03546143	573.03546143
2455309.6074999999	443697.4688	330019.2812	330019.2812	628.98815918	568.58978271	568.58978271
2455309.6082500000	-31.6003	-98.4452	-98.4452	309.86914062	352.03240967	352.03240967
2455309.6089800000	439456.7812	327514.7500	327514.7500	635.14758301	563.59509277	563.59509277
2455309.6097499998	439493.3438	326545.7188	326545.7188	632.70477295	571.52697754	571.52697754
2455309.6105000000	441811.9688	328742.5000	328742.5000	631.09515381	566.79565430	566.79565430
2455309.6112299999	440579.9688	328408.9688	328408.9688	631.86859131	568.62670898	568.62670898
2455309.6120799999	431775.1875	320706.6562	320706.6562	630.82739258	564.10467529	564.10467529
2455309.6128500002	433272.5625	321243.4688	321243.4688	628.89404297	564.30987549	564.30987549
2455309.6135900002	431523.4375	321564.1875	321564.1875	629.87152100	564.17785645	564.17785645
2455309.6143399999	440261.0000	326553.0938	326553.0938	634.67309570	567.54669189	567.54669189
2455309.6151000001	439411.5312	324456.8125	324456.8125	632.33996582	566.85235596	566.85235596
2455309.6158599998	439646.1250	325350.4688	325350.4688	633.61712646	572.77136230	572.77136230
2455309.6165999998	437785.4375	324240.0000	324240.0000	633.36560059	566.96960449	566.96960449
2455309.6173500000	436699.4062	324219.4375	324219.4375	630.96771240	565.37048340	565.37048340
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2455309.6188500002	438373.8750	325027.0000	325027.0000	634.56488037	569.13177490	569.13177490
2455309.6195700001	438494.5000	323463.2500	323463.2500	633.46362305	567.54522705	567.54522705
2455309.6203399999	436221.0000	323727.0938	323727.0938	632.80133057	567.45831299	567.45831299
2455309.6210900000	435898.9062	323663.1562	323663.1562	634.63916016	569.53729248	569.53729248
2455309.6218200000	436609.4062	324211.2188	324211.2188	633.99578857	565.14093018	565.14093018
2455309.6225600000	435605.0625	321923.8438	321923.8438	629.20562744	562.57165527	562.57165527
2455309.6233199998	433474.5625	323253.7812	323253.7812	631.88623047	565.15844727	565.15844727
2455309.6240699999	435258.9688	323046.5000	323046.5000	629.73913574	570.21923828	570.21923828
2455309.6247899998	432652.7188	320552.6562	320552.6562	632.03057861	564.70739746	564.70739746
2455309.6255600001	432509.7188	319726.4375	319726.4375	631.10437012	568.65039062	568.65039062
2455309.6263299999	429810.4375	318152.6250	318152.6250	631.02233887	565.93231201	565.93231201
2455309.6270900001	429311.2500	317995.6250	317995.6250	627.34887695	564.46801758	564.46801758

2455309.6278499998	425861.9375	314579.1250	314579.1250	629.35443115	564.44903564	564.44903564
2455309.6285899999	429869.0938	318695.7500	318695.7500	630.99407959	565.24176025	565.24176025
2455309.6293400000	429331.8125	317795.2500	317795.2500	633.98297119	567.70214844	567.70214844
2455309.6300900001	427088.7500	316670.3438	316670.3438	631.28680420	563.50671387	563.50671387
2455309.6308400002	186975.7031	NaN	NaN	497.62069702	NaN	NaN
2455309.6316000000	425065.6562	313977.6875	313977.6875	630.58117676	563.31353760	563.31353760
2455309.6323699998	425571.1562	316240.5625	316240.5625	626.88085938	565.95629883	565.95629883
2455309.6331300000	428142.5625	316511.4688	316511.4688	630.62188721	563.19519043	563.19519043
2455309.6338800001	426176.2812	315495.1250	315495.1250	632.15899658	566.36932373	566.36932373
2455309.6345899999	424899.0625	313506.0625	313506.0625	632.14685059	568.04754639	568.04754639
2455309.6353900000	422019.6562	312722.9688	312722.9688	628.93670654	563.95800781	563.95800781
2455309.6361099998	421715.9688	313272.8750	313272.8750	630.04663086	565.08691406	565.08691406
2455309.6369300000	420736.7188	309496.3438	309496.3438	628.65960693	567.03973389	567.03973389
2455309.6376899998	417810.9375	306956.0000	306956.0000	630.95965576	564.13592529	564.13592529
2455309.6385400002	420354.3125	310259.9375	310259.9375	627.49542236	565.54241943	565.54241943
2455309.6392700002	416004.1250	309276.4375	309276.4375	625.54431152	564.04754639	564.04754639
2455309.6400700002	416305.5625	307851.2188	307851.2188	633.08526611	564.37945557	564.37945557
2455309.6408799998	411961.3438	304070.2188	304070.2188	625.82531738	564.81616211	564.81616211
2455309.6416600002	411911.2188	304438.0312	304438.0312	627.48327637	558.46270752	558.46270752
2455309.6424400001	410182.7500	304507.9688	304507.9688	624.13818359	565.18481445	565.18481445
2455309.6432099999	412033.6875	304404.6562	304404.6562	626.45257568	563.41302490	563.41302490
2455309.6439800002	414579.6250	307558.0938	307558.0938	628.44158936	564.23718262	564.23718262
2455309.6447700001	386868.6250	263720.0312	263720.0312	610.72766113	540.90887451	540.90887451
2455309.6455299999	412085.4688	304360.1875	304360.1875	629.94824219	566.86053467	566.86053467
2455309.6617700001	398733.3438	297375.2812	297375.2812	627.92059326	565.05957031	565.05957031
2455309.6625100002	398521.9062	297204.7188	297204.7188	619.46789551	561.64495850	561.64495850
2455309.6632400001	402827.6562	299293.7812	299293.7812	623.23162842	571.49462891	571.49462891
2455309.6639999999	404032.2188	299715.3125	299715.3125	625.56610107	562.76696777	562.76696777
2455309.6647299998	399676.5312	298501.7812	298501.7812	626.43542480	562.04748535	562.04748535
2455309.6654599998	402623.9688	300630.8750	300630.8750	621.54913330	562.32830811	562.32830811
2455309.6661899998	386863.0625	291899.2500	291899.2500	619.21154785	561.13763428	561.13763428
2455309.6669299998	403381.2812	300101.0938	300101.0938	624.49420166	559.26202393	559.26202393
2455309.6677799998	393048.4688	292852.9688	292852.9688	621.02581787	560.05834961	560.05834961
2455309.6685199998	400502.3125	298586.9062	298586.9062	627.39306641	563.60162354	563.60162354

2455309.6692700000	400751.5938	297408.3438	297408.3438	621.72265625	565.18292236	565.18292236
2455309.6700100000	400829.0625	299215.5312	299215.5312	622.00323486	560.67102051	560.67102051
2455309.6708600000	399897.2812	297202.5938	297202.5938	623.06549072	569.10601807	569.10601807
2455309.6715699998	398345.5312	297065.5625	297065.5625	627.40173340	564.22955322	564.22955322
2455309.6723600002	397688.1562	296304.9688	296304.9688	623.23638916	567.72406006	567.72406006
2455309.6730900002	397043.5938	293356.6875	293356.6875	622.68408203	563.07482910	563.07482910
2455309.6739599998	394997.5312	292805.8438	292805.8438	621.30120850	560.44177246	560.44177246
2455309.6746999999	393069.4688	293766.9062	293766.9062	620.42657471	563.76336670	563.76336670
2455309.6755400002	396262.0938	295140.0000	295140.0000	626.56707764	564.64056396	564.64056396
2455309.6762700002	396749.7500	296315.8125	296315.8125	626.14111328	560.88891602	560.88891602
2455309.6770600001	399316.5938	296078.0312	296078.0312	629.36096191	567.89727783	567.89727783
2455309.6778000002	396061.4375	294935.6250	294935.6250	621.01715088	562.61932373	562.61932373
2455309.6785800001	399628.3438	296294.7500	296294.7500	630.14501953	564.25134277	564.25134277
2455309.6793300002	387161.4688	288431.7500	288431.7500	620.91558838	555.87036133	555.87036133
2455309.6800699998	393611.5938	293407.4688	293407.4688	622.03930664	570.83709717	570.83709717
2455309.6808900000	393054.1562	291119.1562	291119.1562	621.04162598	564.97052002	564.97052002
2455309.6816699998	394444.9062	292607.4688	292607.4688	623.54046631	562.21026611	562.21026611
2455309.6824400001	394325.4688	291851.8438	291851.8438	624.19848633	564.04620361	564.04620361
2455309.6834999998	382498.5312	284594.0938	284594.0938	631.09417725	561.30731201	561.30731201
2455309.6842200002	384354.0312	286263.3125	286263.3125	627.83319092	560.44848633	560.44848633
2455309.6851700000	243459.1094	181332.8594	181332.8594	555.63800049	509.13034058	509.13034058
2455309.6858999999	379560.9375	283782.8125	283782.8125	626.40893555	569.08197021	569.08197021
2455309.6867100000	379147.0312	281624.8750	281624.8750	623.98992920	562.00335693	562.00335693
2455309.6874400000	380160.0312	283923.2188	283923.2188	618.68426514	567.40863037	567.40863037
2455309.6883100001	378631.2500	281644.3438	281644.3438	622.48333740	565.38909912	565.38909912
2455309.6890699998	379410.1562	281285.5000	281285.5000	622.60443115	566.04919434	566.04919434
2455309.6900700000	376096.0000	278727.5625	278727.5625	626.78607178	565.33190918	565.33190918
2455309.6908200001	117078.7734	85728.1016	85728.1016	481.51309204	444.74682617	444.74682617
2455309.6916100001	369588.0000	274502.0000	274502.0000	616.04132080	566.38677979	566.38677979
2455309.6923400001	368865.0312	273928.6875	273928.6875	617.77069092	565.91741943	565.91741943
2455309.6933400002	362612.6875	270132.1562	270132.1562	622.83514404	565.17840576	565.17840576
2455309.6942199999	362018.6875	269331.4375	269331.4375	622.79217529	572.29779053	572.29779053
2455309.6949499999	361918.8438	268919.1562	268919.1562	618.52258301	559.74584961	559.74584961
2455309.6958099999	362236.6250	268192.1875	268192.1875	625.54418945	566.32971191	566.32971191

2455309.6965500000	361568.9688	269583.5000	269583.5000	618.60479736	567.68139648	567.68139648
2455309.6974399998	361110.5312	269545.8125	269545.8125	618.71618652	568.18707275	568.18707275
2455309.6982200001	362987.9375	269619.5312	269619.5312	626.66021729	562.73651123	562.73651123
2455309.6989600002	362666.7188	269153.5312	269153.5312	623.76275635	565.97802734	565.97802734
2455309.6997000002	365697.7188	268368.5938	268368.5938	624.01824951	568.52337646	568.52337646
2455309.7004300002	358995.4375	265986.1562	265986.1562	629.23614502	571.95465088	571.95465088
2455309.7012499999	358871.0625	264964.9062	264964.9062	623.96325684	570.65808105	570.65808105
2455309.7020600000	350929.2500	261153.9844	261153.9844	619.71228027	566.61962891	566.61962891
2455309.7029100000	344895.8125	257792.2500	257792.2500	618.43634033	567.81176758	567.81176758
2455309.7036600001	334603.5312	249275.6094	249275.6094	615.44537354	567.84100342	567.84100342
2455309.7045399998	328423.6875	243779.5312	243779.5312	614.76507568	566.62060547	566.62060547
2455309.7052799999	328867.7188	242675.2656	242675.2656	619.80401611	574.67663574	574.67663574
2455309.7061500000	319402.4375	235703.6406	235703.6406	613.10424805	565.15393066	565.15393066
2455309.7068800000	259735.2188	189294.9531	189294.9531	601.28033447	558.92242432	558.92242432
2455309.7077100002	296147.9375	217415.5625	217415.5625	606.24536133	552.16876221	552.16876221
2455309.7084599999	329007.7500	244936.0000	244936.0000	618.29931641	560.71978760	560.71978760
2455309.7093600002	330169.5312	247346.2656	247346.2656	614.86743164	566.30438232	566.30438232
2455309.7101300000	330157.9688	247406.9844	247406.9844	620.38836670	564.51190186	564.51190186
2455309.7108600000	331550.0625	246242.9062	246242.9062	617.31970215	562.89831543	562.89831543
2455309.7115699998	331764.1562	247377.7344	247377.7344	615.26629639	566.31665039	566.31665039
2455309.7124000001	330076.0000	244604.9844	244604.9844	621.56054688	567.84887695	567.84887695
2455309.7131400001	292383.5625	215354.0312	215354.0312	605.32250977	564.67071533	564.67071533
2455309.7138700001	284552.0000	211619.8125	211619.8125	604.58416748	559.14904785	559.14904785
2455309.7145900000	305236.4375	228320.2656	228320.2656	612.11853027	569.03948975	569.03948975
2455309.7154999999	308747.1875	229477.8750	229477.8750	620.70666504	564.63684082	564.63684082
2455309.7162299999	306768.1875	227566.0625	227566.0625	608.48229980	572.08770752	572.08770752
2455309.7170699998	309853.1250	229983.9219	229983.9219	614.75012207	566.23229980	566.23229980
2455309.7178400001	280422.2188	207807.7188	207807.7188	607.83831787	557.85162354	557.85162354
2455309.7187700002	305264.0312	225401.0312	225401.0312	611.75408936	570.31658936	570.31658936
2455309.7195100002	301578.1250	226856.1875	226856.1875	606.72442627	568.31738281	568.31738281
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2455309.7210599999	299091.5312	222038.5625	222038.5625	614.38476562	567.26696777	567.26696777
2455309.7218200001	100907.8516	76937.4453	76937.4453	559.28002930	540.14318848	540.14318848
2455309.7226300002	173033.0312	121619.1797	121619.1797	570.28125000	541.39093018	541.39093018

2455309.7233600002	233642.7969	173223.5938	173223.5938	590.94140625	561.03735352	561.03735352
2455309.7240900001	29397.7363	23757.6895	23757.6895	578.41625977	571.55462646	571.55462646
2455309.7249300000	260491.3750	192962.6094	192962.6094	598.20825195	562.44171143	562.44171143
2455309.7256900002	282388.0312	211242.3906	211242.3906	606.35479736	562.99542236	562.99542236
2455309.7265300001	189798.5312	141044.3438	141044.3438	584.49322510	558.99707031	558.99707031
2455309.7272600001	218880.6250	160811.2812	160811.2812	596.90582275	555.82354736	555.82354736
2455309.7280799998	193741.8281	143278.8438	143278.8438	583.86157227	549.92956543	549.92956543
2455309.7289499999	290068.0312	215466.1094	215466.1094	613.50860596	580.00250244	580.00250244
2455309.7297100001	292867.7500	217173.3906	217173.3906	614.10821533	567.10754395	567.10754395
2455309.7305800002	244540.8594	178198.7344	178198.7344	594.46087646	558.02392578	558.02392578
2455309.7314399998	199900.3750	141638.3906	141638.3906	580.44183350	543.10552979	543.10552979
2455309.7321799998	65954.6484	46033.3594	46033.3594	554.93743896	538.49841309	538.49841309
2455309.7330200002	90091.3281	64659.0703	64659.0703	570.54071045	548.53515625	548.53515625
2455309.7337600002	NaN	-1073.1212	-1073.1212	NaN	731.82720947	731.82720947
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2455309.7353500002	174158.7500	135104.2812	135104.2812	562.01812744	541.25250244	541.25250244
2455309.7361099999	310500.1250	228899.9844	228899.9844	625.00158691	576.52618408	576.52618408
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2455309.7376000001	313204.1562	231880.6094	231880.6094	616.31231689	570.31646729	570.31646729
2455309.7383599998	309759.8438	228940.8594	228940.8594	611.91583252	570.69506836	570.69506836
2455309.7391400002	282769.0938	209276.0469	209276.0469	599.66137695	550.71081543	550.71081543
2455309.7398799998	321503.7500	239595.0312	239595.0312	610.35485840	565.13531494	565.13531494
2455309.7406400000	315256.8438	235986.4531	235986.4531	618.14697266	571.58032227	571.58032227
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2455309.7421200001	205215.2656	NaN	NaN	560.83355713	NaN	NaN
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2455309.7436099998	319096.2812	235852.3281	235852.3281	612.62188721	560.67956543	560.67956543
2455309.7445399999	315674.1250	233443.9375	233443.9375	616.92559814	564.54681396	564.54681396
2455309.7452699998	308981.7500	227438.5156	227438.5156	611.08917236	564.82391357	564.82391357
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2455309.7467200002	301255.5000	223175.4062	223175.4062	610.84783936	557.16412354	557.16412354
2455309.7474699998	290496.0000	216173.0625	216173.0625	613.33563232	561.93963623	561.93963623
2455309.7481900002	282895.1875	208781.8594	208781.8594	607.83209229	566.35363770	566.35363770
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2455309.7496600002	285989.7188	211527.6875	211527.6875	601.78863525	566.54980469	566.54980469
2455309.7503900002	281896.0000	207676.0156	207676.0156	606.59692383	561.90740967	561.90740967
2455309.7511300002	272877.8750	203574.5312	203574.5312	605.02532959	566.99725342	566.99725342
2455309.7518900000	276114.7812	203840.4844	203840.4844	600.67303467	554.35614014	554.35614014
2455309.7526500002	274444.1250	203268.8281	203268.8281	604.69079590	560.31561279	560.31561279
2455309.7533800001	265559.8750	197219.0625	197219.0625	596.75274658	555.81848145	555.81848145
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2455309.7555700000	250318.7500	184642.7031	184642.7031	594.70806885	551.52270508	551.52270508
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2455309.7570400001	243416.8438	181775.1562	181775.1562	592.97943115	550.21582031	550.21582031
2455309.7578099999	234454.8125	175104.1562	175104.1562	585.19744873	555.37493896	555.37493896
2455309.7585600000	210213.5625	155377.0312	155377.0312	583.24383545	537.94635010	537.94635010
2455309.7593299998	44840.1328	31999.5488	31999.5488	559.47186279	540.49029541	540.49029541
2455309.7600599998	99.0000	99.0000	99.0000	559.47186279	540.49029541	540.49029541
2455309.7607999998	-306.9564	NaN	NaN	623.09295654	NaN	NaN
2455309.7615499999	99.0000	99.0000	99.0000	623.09295654	NaN	NaN
2455309.7623000001	121.5827	741.4514	741.4514	637.30108643	643.76922607	643.76922607
2455309.7630599998	-27.8492	NaN	NaN	664.07470703	NaN	NaN
2455309.7638099999	NaN	-375.5495	-375.5495	NaN	702.67559814	702.67559814
2455309.7645399999	389.0544	1577.1559	1577.1559	660.08862305	661.12518311	661.12518311
2455309.7652799999	-699.1352	-226.9464	-226.9464	701.18121338	689.78479004	689.78479004
2455309.7660200000	99.0000	99.0000	99.0000	701.18121338	689.78479004	689.78479004
2455309.7667500000	772.2776	73.9884	73.9884	704.56378174	699.63360596	699.63360596

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#GJD	target	reference1	reference2	error	ref.1err.	ref.2err.
2455313.6929100002	485583.1250	361443.3438	361443.3438	650.55078125	585.06164551	585.06164551
2455313.6937799999	487938.6250	359060.5938	359060.5938	654.61260986	581.29138184	581.29138184
2455313.6948299999	612827.4375	456179.4062	456179.4062	733.71716309	652.86920166	652.86920166
2455313.6959000002	626281.1250	464466.0312	464466.0312	741.98516846	656.89660645	656.89660645
2455313.6968499999	508302.9688	378083.1562	378083.1562	692.00726318	638.02282715	638.02282715
2455313.6977900001	607552.3750	452119.8750	452119.8750	733.78924561	653.60913086	653.60913086
2455313.6987999999	623919.1250	461779.4062	461779.4062	738.91101074	656.16607666	656.16607666

2455313.7001200002	765721.9375	568384.5625	568384.5625	821.91271973	731.40411377	731.40411377
2455313.7011699998	758464.8125	564425.2500	564425.2500	819.83990479	729.84173584	729.84173584
2455313.7022199999	747117.2500	555952.8750	555952.8750	815.63092041	731.02508545	731.02508545
2455313.7034000000	755798.0625	562954.3125	562954.3125	816.96203613	731.30450439	731.30450439
2455313.7045100001	757168.5000	561696.6875	561696.6875	819.43487549	731.51593018	731.51593018
2455313.7055799998	695030.5625	518200.3750	518200.3750	796.99151611	718.26702881	718.26702881
2455313.7067000000	738933.5000	552652.8750	552652.8750	818.23358154	732.01995850	732.01995850
2455313.7078499999	722682.8125	537451.1875	537451.1875	807.95416260	718.92517090	718.92517090
2455313.7088799998	749408.0000	557053.6250	557053.6250	820.10485840	726.84106445	726.84106445
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2455313.7109699999	738706.3125	549776.3750	549776.3750	812.06536865	729.25494385	729.25494385
2455313.7120300001	728730.6250	543113.9375	543113.9375	814.82629395	723.48297119	723.48297119
2455313.7130800001	741811.9375	549770.8125	549770.8125	820.75372314	728.51831055	728.51831055
2455313.7142599998	725992.1875	540647.2500	540647.2500	814.31811523	723.23193359	723.23193359
2455313.7153099999	749644.6250	555973.0625	555973.0625	814.08459473	726.26062012	726.26062012
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2455313.7175500002	744830.1875	555390.6875	555390.6875	821.09344482	730.67950439	730.67950439
2455313.7185999998	713147.5000	532167.6875	532167.6875	814.64324951	727.66589355	727.66589355
2455313.7197799999	735563.0000	549820.3750	549820.3750	819.75122070	734.68115234	734.68115234
2455313.7209500000	383759.0938	285357.3438	285357.3438	685.10815430	620.76513672	620.76513672
2455313.7219699998	724143.9375	538125.0000	538125.0000	810.12249756	723.46203613	723.46203613
2455313.7230300000	722197.7500	533663.0625	533663.0625	813.64019775	724.56201172	724.56201172
2455313.7241900000	711624.8125	530039.9375	530039.9375	815.75665283	724.32696533	724.32696533
2455313.7253000000	724620.6875	539570.5000	539570.5000	812.59265137	723.67034912	723.67034912
2455313.7263500001	726975.0000	541292.8125	541292.8125	815.03460693	728.84411621	728.84411621
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2455313.7296799999	714563.0625	532821.0000	532821.0000	813.16040039	725.36145020	725.36145020
2455313.7307300000	711090.4375	526541.6875	526541.6875	810.39501953	724.77026367	724.77026367
2455313.7319999998	715838.1250	532274.8125	532274.8125	809.90905762	730.69158936	730.69158936
2455313.7330299998	715306.6875	531337.4375	531337.4375	811.43627930	723.73266602	723.73266602
2455313.7340600002	621151.6250	452868.3750	452868.3750	783.31579590	699.16125488	699.16125488
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2455313.7361499998	712425.1250	528434.1250	528434.1250	811.70642090	729.81475830	729.81475830

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2455313.7384000001	704528.5000	524881.8125	524881.8125	812.41143799	726.46295166	726.46295166
2455313.7394099999	694461.0000	517719.0000	517719.0000	808.57421875	728.70794678	728.70794678
2455313.7406100002	695978.1875	516648.5938	516648.5938	805.33361816	722.79101562	722.79101562
2455313.7417899999	693926.1250	517037.4375	517037.4375	801.23187256	723.38641357	723.38641357
2455313.7428000001	691831.8125	511563.6250	511563.6250	803.85845947	729.68505859	729.68505859
2455313.7439500000	667654.8125	490990.2812	490990.2812	800.00201416	713.25946045	713.25946045
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2455313.7493900000	666722.3125	496322.1562	496322.1562	799.01519775	716.04327393	716.04327393
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2455313.7514900002	667569.7500	494656.4375	494656.4375	800.57067871	717.91717529	717.91717529
2455313.7525100000	655142.9375	487264.1875	487264.1875	794.67785645	716.72143555	716.72143555
2455313.7536900002	659730.8125	490471.8125	490471.8125	800.07122803	717.48999023	717.48999023
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2455313.7558300002	NaN NaN NaN	NaN NaN NaN				
2455313.7568700002	531743.6250	397288.5000	397288.5000	756.44329834	688.02246094	688.02246094
2455313.7579500000	608407.8125	450838.2500	450838.2500	792.22418213	725.77142334	725.77142334
2455313.7589900000	NaN 260485.6250	260485.6250	NaN 618.92395020	618.92395020		
2455313.7601700001	644079.7500	481838.0000	481838.0000	800.66601562	721.17364502	721.17364502
2455313.7611900000	642514.5000	474869.7188	474869.7188	796.15362549	718.88085938	718.88085938
2455313.7623399999	630069.0625	467021.5000	467021.5000	796.69305420	717.79516602	717.79516602
2455313.7633600002	622436.1875	463586.7812	463586.7812	792.35504150	716.59490967	716.59490967
2455313.7643700000	626193.4375	460201.5625	460201.5625	790.64611816	708.54711914	708.54711914
2455313.7655400001	603480.6250	448731.1562	448731.1562	781.89978027	707.64581299	707.64581299
2455313.7665700000	614118.4375	450473.9375	450473.9375	789.58666992	710.20648193	710.20648193
2455313.7676300001	601181.3750	446144.8438	446144.8438	784.45782471	708.71704102	708.71704102
2455313.7686500000	595473.6875	445133.6875	445133.6875	787.87799072	703.71282959	703.71282959
2455313.7697100001	569978.8125	425672.4688	425672.4688	783.87298584	702.45080566	702.45080566
2455313.7708899998	528943.2500	397640.0625	397640.0625	785.70446777	713.91412354	713.91412354
2455313.7720400002	559021.4375	414133.8750	414133.8750	780.46789551	695.96636963	695.96636963
2455313.7731200000	578124.8750	427461.8438	427461.8438	780.02593994	709.75378418	709.75378418

2455313.7745800000	732765.3750	548553.6250	548553.6250	878.52038574	797.14245605	797.14245605
2455313.7758200001	751898.6875	560567.0000	560567.0000	894.91967773	801.54345703	801.54345703
2455313.7774399999	920003.7500	689378.5000	689378.5000	1015.89929199	915.40362549	915.40362549
2455313.7789099999	945282.2500	700128.2500	700128.2500	1015.93359375	919.60235596	919.60235596
2455313.7803799999	940574.7500	686428.5625	686428.5625	1013.10687256	913.89392090	913.89392090
2455313.7818200001	898884.7500	669926.6250	669926.6250	1004.49755859	910.52679443	910.52679443
2455313.7922999999	875706.8750	655651.1250	655651.1250	1028.28430176	966.21441650	966.21441650
2455313.7938700002	886290.5625	662115.3750	662115.3750	1042.17431641	959.57067871	959.57067871
2455313.7954099998	630750.6250	474674.6562	474674.6562	999.40509033	932.73376465	932.73376465
2455313.7971100002	885193.1250	665596.9375	665596.9375	1040.07202148	950.75714111	950.75714111
2455313.7986499998	320225.3750	232130.1875	232130.1875	898.24328613	842.86120605	842.86120605
2455313.8001999999	885239.0000	657532.1250	657532.1250	1047.99255371	956.22973633	956.22973633
2455313.8064199998	223342.8125	NaN	NaN	778.97583008	NaN	NaN
2455313.8575800001	231280.5938	188714.6094	188714.6094	784.57574463	737.05499268	737.05499268
2455313.8588899998	245201.4688	NaN	NaN	773.05847168	NaN	NaN
2455313.8607600001	NaN	347807.6250	347807.6250	NaN	908.36279297	908.36279297
2455313.8627700000	313902.4062	230459.8125	230459.8125	793.57409668	740.53607178	740.53607178
2455313.8645000001	NaN	113923.0781	113923.0781	NaN	525.44567871	525.44567871
2455313.8654999998	145324.2969	114521.7656	114521.7656	556.49072266	517.22247314	517.22247314
2455313.8664600002	NaN	64521.6016	64521.6016	NaN	543.45227051	543.45227051
2455313.8673800002	99.0000	99.0000	99.0000	NaN	543.45227051	543.45227051
2455313.8682300001	2284.1201	82932.8359	82932.8359	523.36035156	523.07788086	523.07788086
2455313.8772000000	NaN	NaN	NaN	NaN	NaN	NaN
2455313.8781800000	99.0000	99.0000	99.0000	NaN	NaN	NaN
2455313.8790500001	99.0000	99.0000	99.0000	NaN	NaN	NaN
2455313.8799200002	NaN	620.0547	620.0547	NaN	483.14108276	483.14108276
2455313.8807899999	99.0000	99.0000	99.0000	NaN	483.14108276	483.14108276
2455313.8816600000	99.0000	99.0000	99.0000	NaN	483.14108276	483.14108276
2455313.8825200000	99.0000	99.0000	99.0000	NaN	483.14108276	483.14108276
2455313.8833900001	99.0000	99.0000	99.0000	NaN	483.14108276	483.14108276
2455313.8843700001	99.0000	99.0000	99.0000	NaN	483.14108276	483.14108276
2455313.8853000002	99.0000	99.0000	99.0000	NaN	483.14108276	483.14108276
2455313.8862200002	99.0000	99.0000	99.0000	NaN	483.14108276	483.14108276
2455313.8870899999	NaN	NaN	NaN	NaN	NaN	NaN

2455313.8881100002	99.0000	99.0000	99.0000	NaN	NaN	NaN
2455313.8889700002	99.0000	99.0000	99.0000	NaN	NaN	NaN
2455313.8918200000	NaN	NaN	NaN	NaN	NaN	NaN
2455313.8936000001	99.0000	99.0000	99.0000	NaN	NaN	NaN
2455313.8945599999	99.0000	99.0000	99.0000	NaN	NaN	NaN
2455313.8963500001	-506.8527	985.9797	985.9797	777.99664307	766.98815918	766.98815918
2455313.8975499999	99.0000	99.0000	99.0000	777.99664307	766.98815918	766.98815918
2455313.8988700002	99.0000	99.0000	99.0000	777.99664307	766.98815918	766.98815918
2455313.9000700000	99.0000	99.0000	99.0000	777.99664307	766.98815918	766.98815918
2455313.9011700000	NaN	NaN	NaN	NaN	NaN	NaN
2455313.9022800000	2076.9348	5557.7637	5557.7637	1247.30932617	1223.30883789	1223.30883789
2455313.9034600002	NaN	NaN	NaN	NaN	NaN	NaN
2455313.9045699998	14951.3955	6488.7456	6488.7456	1551.30737305	1588.00866699	1588.00866699
2455313.9062500000	99.0000	99.0000	99.0000	1551.30737305	1588.00866699	1588.00866699
2455313.9091400001	NaN	NaN	NaN	NaN	NaN	NaN

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#GJD	target	reference1	reference2	error	ref.1err.	ref.2err.
2455210.5097300000	718372.1250	646393.3750	646393.3750	726.01190186	693.91461182	693.91461182
2455210.5111099998	NaN	652396.1875	652396.1875	NaN	696.89709473	696.89709473
2455210.5125099998	723198.1875	656167.2500	656167.2500	728.03698730	698.40539551	698.40539551
2455210.5138800000	723987.3125	651846.5000	651846.5000	729.79760742	696.93780518	696.93780518
2455210.5152500002	723554.3750	648548.3125	648548.3125	729.98291016	695.52777100	695.52777100
2455210.5166600002	NaN	NaN	NaN	NaN	NaN	NaN
2455210.5180199998	729274.5625	657648.3125	657648.3125	731.46600342	698.59875488	698.59875488
2455210.5194000001	729275.3750	654377.6250	654377.6250	734.76104736	699.64031982	699.64031982
2455210.5207799999	727102.7500	656030.7500	656030.7500	729.97583008	698.30718994	698.30718994
2455210.5221400000	740816.6250	663968.6250	663968.6250	735.87976074	701.12561035	701.12561035
2455210.5235400000	735889.2500	660919.4375	660919.4375	734.64190674	699.53900146	699.53900146
2455210.5249100002	NaN	669100.7500	669100.7500	NaN	702.99804688	702.99804688
2455210.5263000000	738906.7500	671671.6875	671671.6875	736.53210449	706.03619385	706.03619385
2455210.5277000000	NaN	666548.6250	666548.6250	NaN	703.22937012	703.22937012
2455210.5290899999	NaN	670305.4375	670305.4375	NaN	704.98461914	704.98461914
2455210.5304999999	739531.0625	669436.6250	669436.6250	737.39666748	704.44744873	704.44744873

2455210.5318999998	739973.1875	671888.0000	671888.0000	738.78442383	708.45318604	708.45318604
2455210.5332800001	NaN	671905.0000	671905.0000	NaN	703.95727539	703.95727539
2455210.5347099998	741595.0000	667048.8125	667048.8125	738.44433594	703.58758545	703.58758545
2455210.5360900001	747647.9375	673243.8125	673243.8125	740.95764160	705.71087646	705.71087646
2455210.5374500002	744651.7500	670067.0625	670067.0625	740.61370850	705.90753174	705.90753174
2455210.5388199999	744628.9375	668774.1250	668774.1250	739.06127930	703.86535645	703.86535645
2455210.5402099998	753090.3750	677465.1875	677465.1875	741.25164795	706.85156250	706.85156250
2455210.5415900000	754415.3750	679888.5625	679888.5625	741.27905273	707.73004150	707.73004150
2455210.5429600002	NaN	682588.0625	682588.0625	NaN	707.73986816	707.73986816
2455210.5443500001	752970.0000	683319.6250	683319.6250	740.83428955	709.58282471	709.58282471
2455210.5457400000	NaN	681021.3125	681021.3125	NaN	707.13061523	707.13061523
2455210.5471100002	756236.0625	681158.5000	681158.5000	743.61962891	710.31091309	710.31091309
2455210.5484699998	756733.6250	685065.9375	685065.9375	744.24444580	710.46838379	710.46838379
2455210.5498700002	756495.6875	686883.9375	686883.9375	742.58636475	710.46368408	710.46368408
2455210.5512399999	762619.8750	683195.9375	683195.9375	745.64184570	710.03790283	710.03790283
2455210.5526200002	755505.4375	680058.8125	680058.8125	743.29034424	708.61071777	708.61071777
2455210.5539799999	763516.2500	688076.0000	688076.0000	745.98437500	711.57800293	711.57800293
2455210.5553500000	762293.6875	690681.6250	690681.6250	746.22583008	715.08367920	715.08367920
2455210.5568100000	753849.1875	681480.9375	681480.9375	745.70806885	711.12786865	711.12786865
2455210.5581800002	765241.7500	689524.9375	689524.9375	746.42480469	712.83837891	712.83837891
2455210.5595600000	757688.0625	684231.5625	684231.5625	746.20776367	710.39245605	710.39245605
2455210.5609400002	766454.5000	692780.3125	692780.3125	747.05468750	713.08355713	713.08355713
2455210.5623100000	769172.3750	693230.4375	693230.4375	749.86383057	714.24499512	714.24499512
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2455210.5650800001	760627.8125	690912.0000	690912.0000	747.38195801	714.74035645	714.74035645
2455210.5664700000	774593.6875	694670.1875	694670.1875	750.14587402	713.31005859	713.31005859
2455210.5678400001	768511.6250	693778.3125	693778.3125	749.21044922	714.26934814	714.26934814
2455210.5691999998	772026.8125	693997.6250	693997.6250	749.41174316	713.36621094	713.36621094
2455210.5705700000	771404.6875	696073.8750	696073.8750	750.29907227	716.29833984	716.29833984
2455210.5719300001	767106.6250	692815.4375	692815.4375	748.57073975	714.76361084	714.76361084
2455210.5733099999	772647.3125	695851.1875	695851.1875	750.20336914	715.85290527	715.85290527
2455210.5746900002	774101.1875	696579.2500	696579.2500	751.64746094	715.89666748	715.89666748
2455210.5760900001	776064.6875	700638.5625	700638.5625	752.31072998	717.98083496	717.98083496
2455210.5774800000	770595.9375	694027.0625	694027.0625	750.87359619	716.20123291	716.20123291

2455210.5788900000	774825.2500	699411.8125	699411.8125	750.00872803	717.38812256	717.38812256
2455210.5802500001	775988.6875	701025.8125	701025.8125	750.10729980	718.28997803	718.28997803
2455210.5816600001	772811.3750	698853.1250	698853.1250	752.34130859	719.16613770	719.16613770
2455210.5830299999	778053.9375	703017.4375	703017.4375	752.11907959	718.55975342	718.55975342
2455210.5844000001	781635.2500	707493.2500	707493.2500	752.78967285	719.40069580	719.40069580
2455210.5857799998	782726.6250	704591.5000	704591.5000	753.94683838	718.18957520	718.18957520
2455210.5871400000	780907.5625	703761.8750	703761.8750	754.48461914	718.56011963	718.56011963
2455210.5885299998	782628.5625	706312.3125	706312.3125	752.73840332	716.29016113	716.29016113
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2455210.5912700002	787823.8125	706195.9375	706195.9375	755.95935059	719.42956543	719.42956543
2455210.5926399999	779463.8750	706439.6875	706439.6875	752.43646240	718.81274414	718.81274414
2455210.5940299998	787960.0000	707916.5625	707916.5625	756.21984863	720.15020752	720.15020752
2455210.5954100001	785447.0000	710081.5000	710081.5000	754.43542480	720.87194824	720.87194824
2455210.5967899999	NaN NaN NaN	NaN NaN NaN				
2455210.5981800002	782034.6250	702492.1875	702492.1875	756.25518799	719.66845703	719.66845703
2455210.5995800002	781574.8750	704316.9375	704316.9375	756.85778809	722.23437500	722.23437500
2455210.6009600000	99.0000	99.0000	99.0000	756.85778809	722.23437500	722.23437500
2455210.6023499998	789430.0625	710641.0000	710641.0000	757.00610352	721.08325195	721.08325195
2455210.6037300001	787843.0000	712404.8125	712404.8125	756.85412598	721.48547363	721.48547363
2455210.6050999998	788144.3125	712588.1875	712588.1875	755.15454102	721.67279053	721.67279053
2455210.6064900002	789207.9375	715428.5625	715428.5625	756.06811523	722.78039551	722.78039551
2455210.6078900001	788642.0000	710360.1250	710360.1250	757.15527344	721.85302734	721.85302734
2455210.6092500002	794483.2500	715629.4375	715629.4375	757.49658203	723.29968262	723.29968262
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2455210.6120000002	NaN NaN NaN	NaN NaN NaN				
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2455210.6147300000	NaN NaN NaN	NaN NaN NaN				
2455210.6161099998	792579.0000	715708.8125	715708.8125	757.73632812	722.98718262	722.98718262
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2455210.6188900000	797943.3750	718937.0000	718937.0000	759.23425293	723.65350342	723.65350342
2455210.6202699998	795868.3750	716196.3750	716196.3750	758.56738281	722.89227295	722.89227295
2455210.6216300000	796537.6250	715859.2500	715859.2500	757.84985352	721.09545898	721.09545898
2455210.6230000001	797905.0625	718559.3750	718559.3750	759.46582031	721.92932129	721.92932129
2455210.6243900000	794072.8750	716929.5000	716929.5000	759.25372314	723.40661621	723.40661621

2455210.6257500001	793875.8750	718130.9375	718130.9375	758.70953369	724.26397705	724.26397705
2455210.6271500001	797579.1250	718844.8750	718844.8750	759.65368652	723.67169189	723.67169189
2455210.6285199998	787309.4375	706468.6250	706468.6250	760.57940674	723.46203613	723.46203613
2455210.6298799999	802598.1250	724108.8750	724108.8750	759.90509033	725.26135254	725.26135254
2455210.6312600002	802031.0625	721311.1250	721311.1250	760.67407227	723.83319092	723.83319092
2455210.6326400000	801512.3750	722905.9375	722905.9375	759.59149170	722.73138428	722.73138428
2455210.6340000001	802565.9375	723680.9375	723680.9375	760.73419189	725.95922852	725.95922852
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2455210.6367700002	NaN NaN NaN	NaN NaN NaN				
2455210.6381500000	798905.1875	719049.7500	719049.7500	761.14947510	723.55200195	723.55200195
2455210.6395100001	802882.8750	722112.6875	722112.6875	759.58929443	721.76330566	721.76330566
2455210.6408899999	799830.5000	722661.0625	722661.0625	760.41101074	725.37017822	725.37017822
2455210.6422600001	799367.7500	723796.1875	723796.1875	759.05401611	724.68634033	724.68634033
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2455210.6533300001	801309.3125	723765.3125	723765.3125	759.59155273	723.77081299	723.77081299
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2455210.6560600000	806109.9375	724984.5625	724984.5625	760.10461426	722.75207520	722.75207520
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2455210.6615599999	803906.5625	726314.3125	726314.3125	760.24401855	723.69256592	723.69256592
2455210.6629400002	804501.2500	726056.6250	726056.6250	759.74511719	723.61077881	723.61077881
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2455210.6725599999	803080.8750	723184.3750	723184.3750	758.14172363	721.41754150	721.41754150
2455210.6739400001	806773.9375	725032.8125	725032.8125	758.80865479	720.68182373	720.68182373
2455210.6752999998	809691.1875	728926.0625	728926.0625	760.24890137	722.61553955	722.61553955
2455210.6766700000	NaN	NaN	NaN	NaN	NaN	NaN
2455210.6780400001	NaN	802795.5625	802795.5625	NaN	758.52960205	758.52960205
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2455210.6821499998	724263.4375	NaN	NaN	719.17248535	NaN	NaN
2455210.6835200000	806517.8750	726069.6250	726069.6250	757.96807861	721.97277832	721.97277832
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2455210.6876300001	NaN	NaN	NaN	NaN	NaN	NaN
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2455210.6931500002	99.0000	99.0000	99.0000	757.28216553	720.17333984	720.17333984
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2455210.7190700001	NaN	NaN	NaN	NaN	NaN	NaN
2455210.7204399998	NaN	NaN	NaN	NaN	NaN	NaN
2455210.7218100000	821056.2500	741629.9375	741629.9375	760.46722412	724.05291748	724.05291748
2455210.7232100000	819593.3125	741092.8750	741092.8750	760.66558838	723.85839844	723.85839844
2455210.7245800002	NaN	NaN	NaN	NaN	NaN	NaN
2455210.7259600000	NaN	NaN	NaN	NaN	NaN	NaN
2455210.7273400002	NaN	NaN	NaN	NaN	NaN	NaN
2455210.7287200000	NaN	NaN	NaN	NaN	NaN	NaN
2455210.7300900002	NaN	NaN	NaN	NaN	NaN	NaN

2455210.7314700000	NaN	NaN	NaN	NaN	NaN	NaN			
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2455210.7383300001	NaN	NaN	NaN	NaN	NaN	NaN			
2455210.7397200000	NaN	NaN	NaN	NaN	NaN	NaN			
2455210.7410900001	822156.9375	739301.1250	739301.1250	762.38195801	723.19293213	723.19293213			
2455210.7424800000	NaN	NaN	NaN	NaN	NaN	NaN			
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2455210.7452799999	NaN	740251.6875	740251.6875	NaN	724.05639648	724.05639648			
2455210.7466899999	NaN	NaN	NaN	NaN	NaN	NaN			
2455210.7480600001	NaN	742406.6875	742406.6875	NaN	724.03686523	724.03686523			
2455210.7494299999	NaN	NaN	NaN	NaN	NaN	NaN			
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2455210.7521799998	816948.8750	736797.5625	736797.5625	760.57409668	723.21258545	723.21258545			
2455210.7535399999	NaN	742970.3750	742970.3750	NaN	723.35308838	723.35308838			
2455210.7549399999	NaN	741858.3125	741858.3125	NaN	724.76446533	724.76446533			
2455210.7563399998	NaN	740735.0000	740735.0000	NaN	724.06970215	724.06970215			
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2455210.7590999999	823279.5000	742781.8750	742781.8750	760.99493408	723.91845703	723.91845703			
2455210.7604899998	99.0000	99.0000	99.0000	760.99493408	723.91845703	723.91845703			
2455210.7618499999	NaN	742245.8750	742245.8750	NaN	723.39947510	723.39947510			
2455210.7632399998	819215.1875	737428.6250	737428.6250	761.52886963	723.28033447	723.28033447			
2455210.7646200000	822385.1875	740314.3125	740314.3125	761.26293945	723.10028076	723.10028076			
2455210.7660099999	818721.1250	738677.6250	738677.6250	760.03686523	723.59027100	723.59027100			
2455210.7673999998	NaN	740459.9375	740459.9375	NaN	721.80468750	721.80468750			
2455210.7687700000	NaN	NaN	NaN	NaN	NaN	NaN			
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2455210.7728700000	NaN	740054.3750	740054.3750	NaN	722.03234863	722.03234863			
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2455210.7756099999	NaN	741477.2500	741477.2500	NaN	723.30688477	723.30688477			
2455210.7769800001	NaN	742629.6250	742629.6250	NaN	722.97058105	722.97058105			

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2455210.7797099999	818197.0625	738096.1250	738096.1250	760.38018799	723.06860352	723.06860352
2455210.7810900002	NaN	741924.2500	741924.2500	NaN	722.18334961	722.18334961
2455210.7824800001	822815.6250	740564.0625	740564.0625	762.63909912	724.03564453	724.03564453
2455210.7838400002	813512.1875	733774.3750	733774.3750	761.79608154	723.59338379	723.59338379
2455210.7852099999	820440.0000	739421.8125	739421.8125	761.43328857	724.79901123	724.79901123
2455210.7865700000	816921.6875	736369.4375	736369.4375	760.09716797	722.87591553	722.87591553
2455210.7879699999	806104.3125	725579.7500	725579.7500	759.40887451	719.60821533	719.60821533
2455210.7893500002	812943.0625	731580.9375	731580.9375	760.77380371	722.65045166	722.65045166
2455210.7907199999	822519.8125	740196.0625	740196.0625	761.29534912	723.63867188	723.63867188
2455210.7920800000	817503.3750	734270.1250	734270.1250	762.05181885	721.44073486	721.44073486
2455210.7934800000	821234.0000	739130.3750	739130.3750	761.60449219	723.54681396	723.54681396
2455210.7948599998	NaN	738816.6875	738816.6875	NaN	723.17993164	723.17993164
2455210.7962400001	820233.6875	737605.7500	737605.7500	762.84838867	722.75671387	722.75671387
2455210.7976000002	819757.1875	737214.3125	737214.3125	762.11004639	723.14105225	723.14105225
2455210.7989800000	815825.3125	732804.3750	732804.3750	762.55444336	724.66748047	724.66748047
2455210.8003600002	NaN	NaN	NaN	NaN	NaN	NaN
2455210.8017400000	814628.7500	731622.3125	731622.3125	762.16973877	721.76727295	721.76727295
2455210.8031000001	819176.4375	737565.0000	737565.0000	762.50122070	724.61309814	724.61309814
2455210.8044799999	817463.8125	736041.9375	736041.9375	760.50494385	722.72961426	722.72961426
2455210.8058400000	824397.6875	738805.1875	738805.1875	761.68273926	722.78747559	722.78747559
2455210.8072299999	821119.7500	739091.0000	739091.0000	761.81451416	724.22290039	724.22290039
2455210.8086100002	816785.6875	736243.8125	736243.8125	761.51281738	724.66418457	724.66418457
2455210.8100000001	820861.9375	739177.8125	739177.8125	763.01202393	725.70050049	725.70050049
2455210.8113799999	816606.3750	732530.6250	732530.6250	764.14959717	723.70452881	723.70452881
2455210.8127500000	815498.3125	732117.0000	732117.0000	762.15716553	723.58996582	723.58996582
2455210.8141200002	819051.2500	736293.2500	736293.2500	763.87506104	724.25659180	724.25659180
2455210.8155000000	819630.1250	734992.3125	734992.3125	762.53851318	722.22070312	722.22070312
2455210.8168600001	823582.3125	740764.8750	740764.8750	762.29211426	724.40502930	724.40502930
2455210.8182399999	821619.5000	737394.7500	737394.7500	763.68096924	724.73992920	724.73992920
2455210.8196100001	823191.7500	740040.1250	740040.1250	765.14526367	723.49633789	723.49633789
2455210.8209699998	820550.9375	738812.0625	738812.0625	761.57885742	723.56219482	723.56219482
2455210.8223700002	825899.1875	739623.3125	739623.3125	764.30566406	723.33483887	723.33483887
2455210.8237800002	818392.1875	733873.5000	733873.5000	762.78967285	723.54382324	723.54382324

2455210.8251600000	810956.7500	726913.1875	726913.1875	762.71752930	722.96551514	722.96551514
2455210.8265300002	818462.5625	733572.3125	733572.3125	762.32202148	721.93640137	721.93640137
2455210.8278899998	814765.6250	732301.0000	732301.0000	763.02819824	723.34643555	723.34643555
2455210.8292800002	824707.5625	739624.5000	739624.5000	763.47399902	724.91101074	724.91101074
2455210.8306600000	820996.6875	737664.9375	737664.9375	762.73315430	724.48645020	724.48645020
2455210.8320300002	822338.7500	736589.8750	736589.8750	764.05706787	723.60021973	723.60021973
2455210.8333899998	823563.4375	735768.4375	735768.4375	763.09466553	722.78723145	722.78723145
2455210.8347900002	820786.5000	735439.6250	735439.6250	762.83758545	722.88903809	722.88903809
2455210.8361599999	818807.1875	734754.1875	734754.1875	763.78131104	723.49035645	723.49035645
2455210.8375599999	815623.8125	731044.6875	731044.6875	764.61267090	723.91162109	723.91162109
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2455210.8402900002	820788.9375	735870.6875	735870.6875	764.06439209	724.02807617	724.02807617
2455210.8416599999	817736.7500	733082.5625	733082.5625	763.52587891	723.95159912	723.95159912
2455210.8430300001	812719.5625	726589.3750	726589.3750	766.47851562	725.65002441	725.65002441
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2455210.8471499998	819125.1250	733118.6875	733118.6875	767.21246338	727.51153564	727.51153564
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2455210.8622900001	819608.5625	732563.2500	732563.2500	764.91558838	723.51708984	723.51708984
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2455210.8650199999	817614.6875	732430.6875	732430.6875	764.10693359	724.20251465	724.20251465
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2455210.8760799998	827799.3125	740818.0625	740818.0625	764.43151855	724.79357910	724.79357910
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2455210.9131800001	819848.5625	735319.5000	735319.5000	762.39459229	723.64642334	723.64642334
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2455210.9187300000	NaN	735682.8125	735682.8125	NaN	724.57904053	724.57904053		
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2455210.9505599998	806684.1250	721618.5000	721618.5000	766.30914307	725.89001465	725.89001465		
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2455210.9533400000	805737.5625	720465.4375	720465.4375	765.11602783	724.49682617	724.49682617		
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2455210.9685600000	NaN	727874.1875	727874.1875	NaN	725.07196045	725.07196045
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2455210.9712999999	NaN	NaN	NaN	NaN	NaN	NaN
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2455210.9740499998	NaN	724491.1875	724491.1875	NaN	726.01049805	726.01049805
2455210.9754300001	NaN	NaN	NaN	NaN	NaN	NaN
2455210.9768099999	NaN	NaN	NaN	NaN	NaN	NaN
2455210.9781800001	NaN	729139.5625	729139.5625	NaN	727.23742676	727.23742676
2455210.9795499998	NaN	NaN	NaN	NaN	NaN	NaN
2455210.9809099999	NaN	NaN	NaN	NaN	NaN	NaN
2455210.9822999998	808645.8750	721830.6875	721830.6875	768.69775391	728.44348145	728.44348145
2455210.9836700000	813848.7500	726966.1875	726966.1875	768.82519531	729.37152100	729.37152100
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2455210.9864200000	NaN	NaN	NaN	NaN	NaN	NaN
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2455210.9947299999	NaN	728197.0625	728197.0625	NaN	770.99920654	770.99920654
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#GJD	target	reference1	reference2	error	ref.1err.	ref.2err.
2455316.5572100002	NaN	NaN	NaN	NaN	NaN	NaN
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2455316.5614800001	483282.9688	429150.5625	429150.5625	601.59454346	570.85693359	570.85693359
2455316.5619800002	485465.0000	430600.6562	430600.6562	602.67346191	571.57110596	571.57110596
2455316.5624699998	434565.7812	386278.3438	386278.3438	573.01562500	545.49627686	545.49627686
2455316.5629699999	311468.7500	275668.5000	275668.5000	501.14596558	474.58294678	474.58294678
2455316.5634699999	NaN	-116.4866	-116.4866	NaN	210.07586670	210.07586670
2455316.5641800002	316281.6250	280543.7812	280543.7812	519.11804199	496.34548950	496.34548950
2455316.5647300002	313039.1250	277204.6875	277204.6875	516.27972412	495.20852661	495.20852661
2455316.5653900001	236082.5156	209179.8594	209179.8594	473.19158936	452.31552124	452.31552124
2455316.5662300000	360511.2500	319909.2188	319909.2188	573.39801025	549.66510010	549.66510010
2455316.5669200001	394977.3750	350805.6562	350805.6562	599.20074463	573.48834229	573.48834229
2455316.5676400000	293143.1562	259478.0938	259478.0938	544.14807129	528.33905029	528.33905029
2455316.5683599999	528895.0625	467866.5000	467866.5000	668.23077393	636.36816406	636.36816406
2455316.5690299999	99.0000	99.0000	99.0000	668.23077393	636.36816406	636.36816406
2455316.5697699999	318323.0625	283579.1250	283579.1250	567.60369873	547.98632812	547.98632812
2455316.5704600001	291537.3125	257019.7500	257019.7500	557.00280762	529.89257812	529.89257812
2455316.5712299999	359108.8125	316088.3750	316088.3750	593.60748291	564.15576172	564.15576172
2455316.5718999999	520847.2188	461903.3750	461903.3750	663.31506348	633.92529297	633.92529297
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2455316.5851699999	406102.3438	360613.2188	360613.2188	557.17523193	527.71740723	527.71740723			
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2455316.5892800000	518377.1562	460645.7812	460645.7812	622.03381348	589.75146484	589.75146484			
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2455316.5960100000	598694.4375	534169.0000	534169.0000	663.45324707	628.67730713	628.67730713			
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2455316.5976499999	597717.5000	532737.9375	532737.9375	661.30432129	629.17895508	629.17895508
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2455316.5986500001	597539.1875	528250.2500	528250.2500	661.46057129	624.62231445	624.62231445
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2455316.6459700000	593285.3750	527392.3750	527392.3750	661.00592041	627.09777832	627.09777832
2455316.6464600000	596691.5625	530128.3750	530128.3750	662.79321289	628.39215088	628.39215088
2455316.6469700001	600509.6250	529770.5625	529770.5625	663.92004395	627.35119629	627.35119629
2455316.6474700002	595480.6250	530836.9375	530836.9375	661.05126953	628.31463623	628.31463623
2455316.6479699998	574413.9375	515286.8125	515286.8125	651.93902588	620.02386475	620.02386475
2455316.6485799998	596873.1250	529397.7500	529397.7500	662.16369629	626.40606689	626.40606689
2455316.6490600002	595888.8125	526611.5625	526611.5625	664.05932617	624.96209717	624.96209717
2455316.6495699999	99.0000	99.0000	99.0000	664.05932617	624.96209717	624.96209717
2455316.6500700000	592257.4375	527733.5000	527733.5000	660.18609619	628.12304688	628.12304688
2455316.6506900000	592459.8125	525105.8125	525105.8125	660.29919434	625.90936279	625.90936279
2455316.6511900001	NaN	-184.5899	-184.5899	NaN	191.64480591	191.64480591

2455316.6517699999	588416.8750	521415.1250	521415.1250	659.05682373	623.55755615	623.55755615
2455316.6522599999	590166.0625	523176.1562	523176.1562	660.96917725	624.94372559	624.94372559
2455316.6527499999	586803.3750	520195.7188	520195.7188	660.61041260	625.01977539	625.01977539

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#GJD	target	reference1	reference2	error	ref.1err.	ref.2err.
2454770.6425600001	701465.6875	306262.2500	112696.6328	813.60119629	628.56903076	519.41589355
2454770.6432400001	715926.5000	308202.5938	114492.3672	825.60351562	624.39135742	515.04302979
2454770.6439100001	722927.5000	313342.4062	115692.1719	833.92065430	636.00231934	514.50012207
2454770.6445700000	NaN	315439.7188	117967.5703	NaN	635.14459229	514.08435059
2454770.6452299999	728624.6875	314258.5938	117368.0469	828.65344238	638.60662842	522.28295898
2454770.6458999999	732203.1250	316209.0625	115965.0312	835.84967041	636.40850830	513.99658203
2454770.6465699999	730034.3125	316727.0938	117088.9844	827.24932861	635.73144531	519.79919434
2454770.6472200002	726840.9375	315239.8438	116190.7500	832.65240479	639.07208252	521.68774414
2454770.6479400001	724659.1250	312014.2188	115804.4453	829.21960449	631.87371826	524.61608887
2454770.6486300002	719589.9375	310888.3125	114934.2578	830.51446533	633.74438477	514.30767822
2454770.6493600002	719867.1875	313765.7812	115291.6875	827.63452148	634.60595703	520.37268066
2454770.6500800001	688546.3125	298990.5625	108283.1875	824.28436279	632.26330566	518.14062500
2454770.6507500000	712079.0625	306352.4688	114194.6016	828.34069824	631.21801758	515.50708008
2454770.6514200000	720857.1875	310818.7188	NaN	830.48455811	628.91809082	NaN
2454770.6520799999	717464.5000	310086.5000	115593.3672	824.08032227	633.52673340	523.72625732
2454770.6527499999	720732.3750	311669.6875	NaN	826.71429443	636.61956787	NaN
2454770.6534000002	726125.8125	310649.5000	NaN	831.35681152	627.27593994	NaN
2454770.6540700002	719954.0000	310642.1250	115184.8984	825.50421143	636.92431641	510.76852417
2454770.6547500002	723841.8750	312170.0938	114289.5547	827.76831055	634.94250488	516.79650879
2454770.6554100001	721200.1250	312276.6250	115037.9688	820.49652100	634.11260986	513.73388672
2454770.6560800001	722254.2500	311234.9062	115174.9453	826.63928223	636.08709717	517.40869141
2454770.6567400000	707370.2500	307331.2188	113878.2188	829.65997314	642.92089844	524.15985107
2454770.6574100000	681162.8125	297767.5938	110805.2500	816.59045410	629.88360596	520.81481934

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#GJD	target	reference1	reference2	error	ref.1err.	ref.2err.
2455427.6078599999	230133.5312	96671.9766	37993.0586	470.87304688	361.70260620	301.97250366

2455427.6087000002	230335.6875	97190.5469	37335.1953	471.81140137	362.73718262	301.00155640
2455427.6095500002	231883.3906	97628.2500	36709.2695	470.68716431	365.14349365	302.46334839
2455427.6103900000	230846.1562	97341.7266	37488.8320	472.82818604	358.25402832	300.51419067
2455427.6111800000	232097.4688	97072.9375	37818.6328	469.57116699	363.28143311	302.44296265
2455427.6120000002	231994.8438	97851.6328	38030.5430	473.91906738	362.39678955	300.62875366
2455427.6128099998	227854.7188	96600.9688	37529.4609	471.14242554	365.04406738	303.63070679
2455427.6135800001	229573.8750	96479.7969	37552.1172	471.91000366	362.13214111	304.11959839
2455427.6143100001	229557.0625	96568.8281	37572.3984	466.96337891	358.18963623	303.59906006
2455427.6151899998	229703.0312	96550.9453	37739.3164	473.84170532	362.51159668	304.33325195
2455427.6160200001	229292.0312	96964.6406	37383.1055	472.99725342	366.22573853	299.56192017
2455427.6168600000	229342.6094	97049.8047	37208.7188	473.54748535	360.27661133	300.95602417
2455427.6176900002	229537.7188	96574.3047	37640.1016	473.88418579	360.69235229	298.47235107
2455427.6184100001	227523.8125	96563.6719	37674.1680	471.87100220	364.34509277	303.67575073
2455427.6192500000	227593.8438	96600.3438	38100.7891	468.09533691	361.15814209	307.10061646
2455427.6200799998	227503.8281	96673.4219	37314.7461	467.96728516	359.66409302	301.21487427
2455427.6208299999	228223.0938	96349.7891	37344.5234	468.11309814	363.46966553	303.37603760
2455427.6216099998	226333.7500	95847.8750	37324.1250	470.39364624	363.10913086	301.71078491
2455427.6224300000	226347.0312	95960.5000	37066.8867	471.20083618	359.72906494	301.04687500
2455427.6232599998	225788.8906	95522.0078	37108.7031	467.91842651	356.86578369	299.07250977
2455427.6241199998	225097.0781	95318.2188	37134.9688	467.28088379	361.39727783	304.80419922
2455427.6249899999	225472.2969	95789.3828	37188.8281	465.74191284	358.02993774	299.77658081
2455427.6258700001	226017.4844	96582.7109	36729.3672	469.44464111	361.43826294	300.43246460
2455427.6266899998	226834.7031	95293.6016	37224.2812	470.52999878	357.84408569	303.81628418
2455427.6275200001	225411.9688	95889.5391	36840.2344	464.92147827	357.12661743	299.73880005
2455427.6282600001	225749.6719	96132.9141	36406.5977	466.45202637	358.49230957	298.20312500
2455427.6290699998	223949.8906	94785.5156	36954.8594	466.13699341	357.14257812	299.77029419
2455427.6299200002	225854.5312	95842.7188	37714.1797	467.24713135	360.14437866	305.69421387
2455427.6307600001	223804.1875	95513.4141	37156.5586	470.05612183	360.01248169	302.04904175
2455427.6315500000	222532.8125	95324.6641	37360.1992	465.92666626	361.06057739	301.67709351
2455427.6323799998	223334.7500	94808.9219	36312.4766	468.85830688	356.58084106	299.88705444
2455427.6332200002	222863.9375	95647.9219	37216.9180	468.39761353	358.20950317	300.81185913
2455427.6339599998	224503.5781	95312.9609	36259.9609	468.69128418	361.59832764	305.18649292
2455427.6346999998	224364.6250	95801.4922	37222.1406	466.28353882	359.95953369	296.31579590
2455427.6355599998	224240.1094	95385.7969	37189.2227	465.22250366	359.71038818	303.00546265

2455427.6364000002	223951.1094	95303.5000	37210.8516	467.22851562	357.35021973	298.77288818
2455427.6372699998	224303.0938	95218.6641	36811.8984	467.14874268	362.34674072	296.88879395
2455427.6380400001	223778.4688	95204.1484	36698.9023	468.41912842	360.97482300	306.61956787
2455427.6388699999	221204.8594	94945.2812	36826.3164	466.55853271	357.42410278	299.38613892
2455427.6396800000	222317.1406	95251.6250	36758.1016	467.30569458	360.40682983	297.39318848
2455427.6404200001	222037.6094	95220.8438	37224.8672	467.96954346	359.06805420	303.39321899
2455427.6412499999	221910.2812	94772.0312	36549.1445	464.65179443	360.89074707	298.21371460
2455427.6421300001	220464.7500	94206.9688	36238.3750	464.75216675	354.25827026	303.56320190
2455427.6429200000	221076.4375	94247.8203	36608.3867	467.69296265	359.57092285	300.64590454
2455427.6436999999	221483.0938	93885.0938	37061.9961	463.44601440	355.10348511	301.89407349
2455427.6445499999	220953.7656	94660.2500	36665.6758	461.18435669	361.49133301	305.75595093
2455427.6453100001	220933.3906	94798.3750	36725.3125	463.82464600	356.69512939	303.33364868
2455427.6460799999	222014.9375	94607.3359	36650.9922	464.50354004	359.88650513	303.42767334
2455427.6469899998	222651.3906	94594.5859	36840.7578	466.27072144	360.61636353	303.01535034
2455427.6478800001	222785.8281	94161.5156	36927.1562	464.05920410	364.68212891	301.18389893
2455427.6486999998	221513.2812	95050.9531	36716.2422	464.70111084	361.50405884	302.59292603
2455427.6495099999	220682.5469	93843.8516	36221.7148	466.55377197	357.63153076	303.31286621
2455427.6502399999	221606.4688	94878.0938	36417.9961	469.43881226	363.37246704	298.86502075
2455427.6511300001	221277.9844	94861.0859	37134.8008	466.85623169	359.60406494	306.32730103
2455427.6519599999	222237.4844	94521.2266	36754.9492	467.70721436	358.05047607	295.98336792
2455427.6527000000	33.6382	158.9865	-157.8479	271.78781128	247.87541199	257.10766602
2455427.6535200002	221684.2969	94418.0625	36250.1055	467.08200073	358.39202881	301.79336548
2455427.6543899998	221692.1562	94518.4609	36836.9102	468.34686279	357.40228271	300.58157349
2455427.6552300001	222555.4844	94883.0703	36526.3164	469.95053101	361.31378174	298.44821167
2455427.6560900002	222141.5000	94645.7891	36734.1367	462.40124512	358.12677002	300.30801392
2455427.6569599998	220489.7344	94905.1094	35905.9180	461.02514648	361.92443848	299.21109009
2455427.6578400000	221968.7969	94882.5703	37044.1211	462.70254517	360.49868774	305.64776611
2455427.6586000002	222341.3125	94656.7031	36937.2734	466.90319824	359.50915527	299.44589233
2455427.6594199999	222875.9375	94765.2109	36748.1016	469.01168823	357.04794312	299.10061646
2455427.6602699999	222609.8906	95855.1250	36158.8555	465.91320801	356.68466187	299.32235718
2455427.6610800000	223265.7188	95054.1875	37291.4648	466.42117310	355.69888306	296.19345093
2455427.6619699998	222332.4844	94678.9062	36100.4688	465.09658813	354.30392456	297.73318481
2455427.6627500001	223391.5312	95464.5938	36923.5781	465.73757935	362.69345093	297.19860840
2455427.6635400001	222129.7812	94371.6250	36740.4688	464.62298584	356.22348022	295.24212646

2455427.6643800000	220571.3281	93656.2188	36108.2734	463.80191040	357.96057129	298.93017578
2455427.6652400000	224431.0469	94312.8203	36882.9062	465.64669800	363.09445190	299.61041260
2455427.6660300000	221956.7500	94444.5234	36649.7695	465.87905884	359.99368286	299.25906372
2455427.6667700000	222602.9844	94082.9297	36517.8828	465.44000244	359.28472900	297.40298462
2455427.6676400001	222203.2812	95208.4922	36623.8281	464.65219116	355.56082153	298.28530884
2455427.6685400000	224481.5000	95748.3516	37288.5352	465.87326050	357.93191528	298.10440063
2455427.6693299999	223646.1875	93823.3594	36568.4531	465.16537476	357.94891357	302.17001343
2455427.6701600002	222061.4844	94001.0859	36462.2188	464.27917480	355.28927612	301.46960449
2455427.6710399999	221692.8438	94732.7422	36838.6094	466.72409058	358.98724365	298.35671997
2455427.6719200001	223862.4219	94353.3438	36450.7891	470.03744507	356.82687378	301.85504150
2455427.6727999998	223933.6562	93865.9219	37202.3398	464.80471802	358.28793335	302.46194458
2455427.6736300001	223276.0781	94812.0312	37192.3125	464.15090942	356.11993408	300.29403687
2455427.6744400002	223437.6875	94777.4141	36991.0820	463.54916382	358.29107666	299.51641846
2455427.6751999999	222777.1562	95217.5469	36774.5156	465.89468384	358.87887573	299.72021484
2455427.6760499999	220698.1094	94172.0859	36514.5586	461.03320312	361.98077393	301.42431641
2455427.6768700001	221168.0781	92947.3750	35739.5820	466.83410645	356.28158569	299.93542480
2455427.6778099998	223266.8438	93911.5938	36166.6172	464.97601318	356.50689697	302.24856567
2455427.6786799999	223175.4062	94256.0391	36284.5625	463.77899170	360.14419556	300.94396973
2455427.6794900000	222284.2500	94656.3125	35708.3359	464.12081909	360.86972046	297.18093872
2455427.6802699999	221426.4844	94228.6797	36273.8047	463.29400635	358.67340088	297.21173096
2455427.6811099998	222775.4219	94054.0078	36225.0391	464.85293579	356.18115234	300.60263062
2455427.6819400000	222590.9688	93643.1328	36231.5273	463.75509644	357.28372192	299.77401733
2455427.6827699998	222285.8125	93679.6250	35526.1953	463.98284912	359.14813232	304.51879883
2455427.6834999998	221710.1094	92526.6484	36128.1758	465.35394287	358.60623169	299.52798462
2455427.6842200002	219823.6719	93341.2734	35760.1133	461.36663818	354.21322632	298.67196655
2455427.6851599999	222894.6250	92980.0078	36032.8320	467.71066284	355.69995117	304.51119995
2455427.6860099998	221935.4688	93536.5625	36172.1680	466.13229370	361.87380981	302.74829102
2455427.6868400001	220881.9688	93015.7891	35821.0664	467.16851807	357.18572998	300.62756348
2455427.6876699999	220755.4219	92321.5938	36186.2852	467.64309692	356.43826294	297.23403931
2455427.6884400002	219482.0781	92199.3672	36003.4688	463.60922241	354.58792114	301.00863647
2455427.6892599999	220085.2500	93198.3125	36117.4062	462.01940918	357.94674683	301.07034302
2455427.6900900002	220754.4219	93368.6406	35359.4258	463.88220215	358.14877319	297.35958862

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#GJD	target	reference1	reference2	error	ref.1err.	ref.2err.
2455110.6336500002	NaN	39175.2344	25202.2637	NaN	325.75128174	300.25259399
2455110.6344099999	151118.5781	115177.1562	NaN	408.32861328	371.37319946	NaN
2455110.6351899998	150466.5938	113793.4297	NaN	407.02825928	372.26574707	NaN
2455110.6359500000	149638.0625	116447.6172	NaN	409.53430176	376.33245850	NaN
2455110.6367199998	147951.2969	114232.0469	NaN	409.89736938	379.75375366	NaN
2455110.6374900001	150598.4062	115258.2109	104281.6719	413.67861938	376.31796265	368.68655396
2455110.6382599999	149058.9844	114552.7656	NaN	411.11270142	378.78665161	NaN
2455110.6390300002	148903.5312	114322.8203	NaN	411.50244141	377.46649170	NaN
2455110.6397899999	148062.4375	114520.5312	105218.0469	411.09609985	375.79495239	369.36492920
2455110.6405600002	141533.8906	109610.1328	99289.8594	405.97256470	371.17080688	364.86840820
2455110.6413300000	148327.9844	114283.1406	102561.8906	409.70626831	380.29333496	372.11627197
2455110.6420900002	89280.2891	NaN	NaN	366.68920898	NaN	NaN
2455110.6428600000	149759.8438	114494.3672	105713.3984	414.95010376	377.38366699	372.94949341
2455110.6436200002	NaN	104073.1719	92370.2578	NaN	373.30194092	363.31527710
2455110.6444000001	145980.0469	111515.5312	101089.2031	420.49597168	385.44027710	1669.06628418
2455110.6451699999	132376.3750	101270.9609	NaN	403.09103394	373.42849731	NaN
2455110.6459400002	146888.6719	112891.0312	102478.1406	412.62802124	381.35159302	372.03433228
2455110.6466999999	148588.7344	113740.2891	101976.9844	414.30401611	380.54412842	373.91400146
2455110.6474799998	146879.7031	113365.9688	102979.8125	412.44754028	384.64025879	369.12344360
2455110.6482400000	145957.7500	111784.9766	NaN	412.67080688	378.90005493	NaN
2455110.6490000002	142878.9062	110953.0234	100359.4141	406.60122681	379.80429077	369.86532593
2455110.6497800001	147518.2344	113319.1484	103561.6484	412.78182983	376.44711304	374.73202515
2455110.6505399998	125618.7109	96158.9453	85668.8516	399.55648804	372.67755127	362.24200439
2455110.6513100001	144311.2344	113619.3594	102014.6953	414.19744873	383.43728638	368.92169189
2455110.6520699998	108811.3359	82361.6953	NaN	388.51669312	358.29037476	NaN
2455110.6528500002	144471.4688	113683.7734	NaN	414.79946899	381.06051636	NaN
2455110.6536099999	118406.2891	91442.1328	NaN	391.84201050	363.40850830	NaN
2455110.6543700001	146220.2812	112905.5938	102693.9375	415.93081665	383.43316650	374.26846313
2455110.6551500000	142573.6406	109556.5234	100313.8281	413.23654175	380.51266479	373.20211792
2455110.6559100002	145791.4219	111193.2422	103442.7734	416.79797363	376.70907593	375.16946411
2455110.6566800000	145894.0469	113481.4844	NaN	420.12896729	384.44372559	NaN
2455110.6574400002	144970.2812	111318.1797	101566.3047	416.58087158	381.07815552	372.18228149
2455110.6582200001	145644.4219	112063.1641	104118.3906	414.24267578	384.33947754	379.06408691

2455110.6597600002	146919.5938	111981.3516	99072.5391	416.62692261	384.09335327	371.87390137
2455110.6613500002	145427.4531	112336.8203	NaN	424.43853760	384.89739990	NaN
2455110.6621200000	90695.1406	NaN	62440.1016	374.82421875	NaN	347.70581055
2455110.6628800002	144173.7344	110247.2266	99291.0547	417.05715942	388.66595459	378.33404541
2455110.6636600001	127788.8203	102380.0703	93586.5078	405.75753784	380.15496826	372.10034180
2455110.6644199998	142954.0000	111099.6719	97893.1953	420.07711792	382.79791260	374.71569824
2455110.6651900001	131266.8750	102130.2109	91194.7500	412.65368652	381.83862305	369.82006836
2455110.6659599999	122773.9766	89783.4531	NaN	400.96432495	367.01361084	NaN
2455110.6667200001	144091.3594	110208.5547	99351.3750	419.46728516	386.48614502	372.47351074
2455110.6682500001	142758.6875	111749.2422	99756.8047	417.41510010	389.52651978	376.86563110
2455110.6697900002	143203.7188	111694.7891	98414.9375	426.53872681	393.59631348	375.54730225
2455110.6713299998	139916.2500	109623.6250	97535.9766	423.21765137	396.96411133	381.44763184
2455110.6720900000	80290.8438	75780.7891	NaN	373.72360229	370.59002686	NaN
2455110.6728699999	139373.3125	108633.2266	98901.8984	425.60403442	397.28536987	382.86251831
2455110.6736300001	112612.0000	90188.2969	NaN	410.49581909	378.79534912	NaN
2455110.6744100000	124213.6328	102965.1094	85550.5391	412.71005249	386.99249268	373.42684937
2455110.6751899999	139765.6562	107259.0781	NaN	423.33398438	390.34158325	NaN
2455110.6759500001	135271.9688	104648.9688	95497.8672	425.41510010	393.54241943	382.73303223
2455110.6767099998	141391.5781	108968.6562	97153.1641	427.45364380	397.68249512	382.73632812
2455110.6774900001	112292.7734	103288.2188	78593.5000	407.26489258	394.40844727	368.98031616
2455110.6782499999	141425.7812	109272.3125	97998.7188	430.35437012	397.72424316	387.23367310
2455110.6790200002	119816.5469	79019.0469	71628.9062	412.10092163	383.12387085	372.66314697
2455110.6797900000	139316.7344	110134.0938	96136.5547	426.71697998	400.33685303	389.55709839
2455110.6805599998	95264.5469	72042.1328	64642.9453	399.45043945	378.54211426	366.03833008
2455110.6813200000	136100.3438	105114.6484	94634.2891	424.67611694	400.35296631	380.38629150
2455110.6820899998	89892.6719	68104.1484	NaN	396.94238281	371.60354614	NaN
2455110.6828600001	116485.8125	101648.0391	80937.8203	409.84948730	395.63342285	379.34597778
2455110.6836199998	140805.0781	104467.7031	95918.6875	433.87475586	399.55804443	386.96578979
2455110.6844000001	140846.7344	106579.6094	NaN	428.74600220	398.58230591	NaN
2455110.6851599999	139350.9531	106614.0625	95381.4453	430.51107788	399.07125854	391.21197510
2455110.6859400002	132393.6875	100909.1016	91462.4766	422.03948975	398.76309204	387.15814209
2455110.6867000000	140399.4688	106005.1562	95642.4297	431.32626343	405.28378296	395.21179199
2455110.6874699998	133324.1875	100150.0781	NaN	428.94696045	403.47271729	NaN
2455110.6882300000	135214.9375	103278.9453	91283.0312	427.46685791	399.76809692	388.15948486

2455110.6889999998	114851.6250	48737.5547	80285.5156	417.43408203	363.20291138	382.28820801
2455110.6897700001	121315.2266	98111.1016	86964.1641	422.37100220	394.71368408	388.15466309
2455110.6905399999	86540.4844	NaN	NaN	398.92236328	NaN	NaN
2455110.6913100001	132668.0781	101917.9609	90874.5469	431.52532959	404.98953247	394.92419434
2455110.6920799999	136946.7812	94520.0156	85985.5000	432.59338379	398.17471313	389.12976074
2455110.6928500002	134636.1562	96891.5938	91037.7344	431.17309570	401.46902466	391.71972656
2455110.6936100000	125037.6094	NaN	83526.9844	431.47848511	NaN	387.01254272
2455110.6943700002	131492.3750	101008.0156	90832.0391	429.36468506	410.10995483	399.71810913
2455110.6951400000	137354.1875	105181.7109	91943.2031	441.91717529	409.72583008	398.39083862
2455110.6959099998	137172.2500	105297.1406	NaN	446.45278931	414.80651855	NaN
2455110.6966800001	136212.2344	103790.8984	93177.4844	440.20898438	409.91293335	398.49783325
2455110.6974499999	109753.8203	97099.2969	76759.5938	420.38504028	406.80749512	392.32830811
2455110.6982200001	133515.7656	103321.1562	89905.4609	445.07330322	407.62039185	398.78823853
2455110.6989799999	121043.8125	91855.9844	82736.9609	437.58044434	407.65631104	401.95117188
2455110.6997600002	136368.9844	102875.2812	NaN	441.68515015	415.01058960	NaN
2455110.7005200000	111496.5391	80173.0547	NaN	432.65927124	399.77041626	NaN
2455110.7012800002	129366.3125	100511.9219	86925.9922	440.00936890	418.88006592	408.88171387
2455110.7020500000	101265.8125	83598.6328	83283.5781	426.37457275	409.51354980	403.24029541
2455110.7028100002	136468.7031	103287.0703	94145.6172	449.05554199	420.62945557	406.52069092
2455110.7035900000	136096.4688	104883.6406	92462.4922	451.11569214	423.20867920	411.43817139
2455110.7043499998	135056.0625	103100.0625	NaN	451.29479980	430.37680054	NaN
2455110.7051200001	136670.3281	101180.3594	91286.4141	463.36972046	424.93127441	411.34408569
2455110.7058799998	136008.5781	101084.5859	91568.3672	452.99685669	425.05468750	409.57565308
2455110.7066400000	132635.3438	101434.5547	92312.8359	457.04891968	428.98669434	417.07269287
2455110.7074099998	132809.1094	100623.6719	93123.4453	455.33709717	430.46517944	421.71768188
2455110.7081800001	134234.0156	102104.5000	91908.9141	452.54153442	425.79415894	419.45535278
2455110.7089499999	123568.2500	95730.6250	85677.2031	455.71286011	423.88607788	417.49456787
2455110.7097100001	135185.0625	103072.5547	90774.8125	462.95919800	439.38488770	425.18679810
2455110.7104900000	72499.6250	93483.8125	NaN	417.34292603	418.66287231	NaN
2455110.7112500002	130950.5312	100674.2734	88922.7188	455.44729614	428.89196777	422.35229492
2455110.7120099999	123363.5078	93802.9531	85202.4688	453.70208740	428.35409546	426.52093506
2455110.7127800002	132264.1406	99405.5234	90622.3047	470.89312744	437.74951172	434.34234619
2455110.7135500000	117421.0625	88734.8281	78306.3359	454.17877197	433.02835083	426.98483276
2455110.7143199998	127402.9453	97326.0703	NaN	472.33496094	434.01968384	NaN

2455110.7150800000	134671.0156	98765.8281	89890.8984	471.70660400	439.26950073	428.70855713
2455110.7158400002	130579.9922	99478.5156	89395.9844	470.43313599	438.30056763	438.18820190
2455110.7166200001	130589.5469	99529.4141	88165.2500	469.23202515	445.69467163	433.04238892
2455110.7173799998	100878.7578	78331.6094	NaN	451.28778076	430.71118164	NaN
2455110.7181500001	129206.6484	99118.7109	87964.7656	476.21960449	440.80535889	444.20040894
2455110.7189099998	123135.1797	92826.8047	83560.3125	475.49594116	446.04064941	436.64175415
2455110.7196900002	127038.8516	97493.5469	87973.9453	481.03561401	450.39727783	447.19708252
2455110.7204499999	126459.1484	95009.8281	84505.9297	485.79550171	457.02264404	442.07531738
2455110.7212399999	126712.2734	95386.7578	87542.0469	477.34567261	455.91604614	453.55041504

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#GJD target reference1 reference2 error ref.1err. ref.2err.

2455713.5888499999	133.6661	NaN	NaN	620.76446533	NaN	NaN
2455713.5899700001	-777.9207	NaN	1106.5825	633.10437012	NaN	638.36712646
2455713.5910600000	741.0158	92.9850	510.2795	656.91882324	643.13665771	634.62347412
2455713.5922500002	99.0000	99.0000	99.0000	656.91882324	643.13665771	634.62347412
2455713.6085000001	10908.3691	NaN	113.9802	354.66452026	NaN	345.93215942
2455713.6096299998	-528.0020	644.4741	NaN	336.68362427	340.09573364	NaN
2455713.6107800002	627.1954	-437.0129	463.5047	330.60626221	332.96325684	339.11782837
2455713.6118200002	-271.0040	-25.0825	-719.2576	330.26611328	339.19046021	347.50854492
2455713.6128500002	60.3878	-30.8517	914.6915	328.59927368	337.98434448	332.72476196
2455713.6138700000	-348.1914	-4.0261	NaN	347.62475586	335.49099731	NaN
2455713.6149100000	7698.2686	-722.9351	NaN	359.60818481	356.18548584	NaN
2455713.6160100000	324.2741	-37.8426	133.0438	347.82333374	333.04522705	320.49502563
2455713.6172300000	-477.8149	337.9187	NaN	355.03387451	337.49691772	NaN
2455713.6298300000	288465.7812	83261.7500	189545.6094	557.18261719	410.74917603	488.41955566
2455713.6317400001	547709.4375	156175.5469	359528.5938	789.81182861	581.00994873	690.59179688
2455713.6335800001	615402.4375	174791.9531	403201.3438	816.23040771	580.94244385	708.10833740
2455713.6356000002	659071.8125	187816.0781	431720.4375	823.33972168	591.84588623	707.42877197
2455713.6375000002	651801.5625	187400.2656	427111.5312	818.46453857	580.72271729	709.14196777
2455713.6393300002	730765.5000	207023.9531	480671.9688	849.76550293	579.90087891	732.06439209
2455713.6413300000	755864.1250	216256.5312	496894.1250	849.29785156	593.33190918	731.31469727
2455713.6434100000	769254.2500	218811.2656	505255.4062	861.97521973	587.41284180	737.47296143
2455713.6454200000	769567.1250	219150.3438	506319.7812	851.45385742	582.54394531	732.88238525

2455713.6473599998	772836.3750	218112.8281	506249.4062	856.06445312	583.28570557	728.84851074
2455713.6493199999	777940.5625	222703.5156	512597.5312	858.76293945	585.47656250	731.27667236
2455713.6512799999	777405.9375	223759.0938	512624.2188	855.05358887	586.82873535	729.49438477
2455713.6532600001	800718.6250	228719.4844	524461.6250	860.76641846	587.82562256	735.21118164
2455713.6552700000	779907.6875	222244.1094	512928.4062	858.14630127	581.30413818	729.38800049
2455713.6571200001	763297.0000	216503.3594	500331.8125	844.04376221	576.32189941	727.38739014
2455713.6590200001	818773.8750	232734.5469	537487.6250	862.88934326	587.01300049	730.77313232
2455713.6609600000	829203.5625	237482.8281	545152.8750	871.49499512	585.37579346	736.86645508
2455713.6628899998	839899.3125	239572.7969	552154.2500	869.34582520	583.77258301	740.73297119
2455713.6647299998	858887.1250	243913.6719	562198.0000	878.81420898	583.33453369	742.72528076
2455713.6666700002	856845.0000	243946.4688	560308.2500	872.82531738	576.52453613	743.89459229
2455713.6686600000	858849.4375	244429.8594	562671.2500	871.96002197	570.26647949	736.96337891
2455713.6704899999	836813.9375	238566.0312	549320.3750	861.34710693	575.67022705	736.68066406
2455713.6723500001	730957.9375	208069.4844	484189.2188	824.82806396	562.12371826	708.69079590
2455713.6741300002	723118.1875	207685.9219	474141.0938	822.38677979	563.03710938	706.47937012
2455713.6760800001	802711.4375	228327.9375	526881.3750	856.23541260	573.43847656	720.43298340
2455713.6780099999	713325.6250	203309.5781	469868.5000	826.10998535	557.66021729	702.52093506
2455713.6799499998	674224.0625	191789.0312	441921.8438	802.50506592	556.15759277	685.65484619
2455713.6819000002	695812.6250	197843.4062	460079.0625	811.03417969	562.28070068	696.81231689
2455713.6838000002	659432.0000	186854.1094	431238.9688	798.38842773	551.02673340	686.90191650
2455713.6856200001	718127.5000	205687.5000	471974.7500	811.58801270	559.00201416	703.62426758
2455713.6874299999	754762.1250	214778.4062	495355.0312	830.99523926	562.78796387	703.66204834
2455713.6893600002	759806.3125	215774.0625	497707.6250	828.34100342	567.27850342	706.51123047
2455713.6913000001	750450.8750	213356.8906	492969.2500	828.67370605	562.32287598	710.85284424
2455713.6932299999	476357.8750	135799.6250	307520.6562	727.38519287	535.21606445	639.98583984
2455713.6951899999	327856.7500	NaN	214537.0625	678.51654053	NaN	593.72796631
2455713.6971600000	392547.0312	112158.3906	256997.1875	694.76727295	526.82653809	613.07269287
2455713.6991200000	706268.5625	199829.2656	459697.4375	811.76306152	554.64312744	692.91943359
2455713.7009299998	735257.2500	209034.1562	481365.6875	825.57403564	559.14068604	706.82305908
2455713.7028100002	684491.3750	193799.9844	447304.0000	809.44256592	557.35418701	695.90374756
2455713.7048300002	266975.1875	73564.1406	186985.5156	669.67657471	544.60644531	598.35009766
2455713.7067499999	177951.0938	50281.4375	NaN	620.26910400	533.11297607	NaN
2455713.7087599998	264865.8125	76812.2109	172185.8281	663.67431641	528.83966064	589.02648926
2455713.7106900001	234822.5469	66341.0781	152672.3281	639.99725342	537.04876709	597.33587646

2455713.7126000002	132961.4375	52850.3672	NaN	606.44158936	534.87866211	NaN
2455713.7144100000	197582.8750	55640.5625	128501.9766	637.23974609	540.73248291	578.04980469
2455713.7162500001	168238.2031	49275.5898	110667.9297	630.61383057	537.62133789	576.94476318
2455713.7181000002	286995.9375	81688.9922	188479.4062	656.86993408	529.72076416	590.66687012
2455713.7198500000	384425.7812	109579.5625	251435.8594	691.35632324	531.87518311	607.59655762

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#GJD	target	reference1	reference2	error	ref.1err.	ref.2err.
2454869.6266100002	168045.0000	175609.5938	434268.7188	497.05398560	500.60623169	657.67510986
2454869.6272800001	166762.8906	176587.5156	433307.8750	494.47897339	500.58782959	657.14923096
2454869.6279500001	166937.4062	176497.7188	432323.8125	493.06112671	499.85336304	653.22247314
2454869.6286100000	165667.3594	174827.5156	428702.4688	495.69134521	502.44061279	657.02038574
2454869.6292800000	166829.1875	176253.5000	434130.4688	489.84609985	496.53045654	654.31817627
2454869.6299500000	166230.3438	175768.7188	432358.4688	493.50433350	504.59396362	652.51824951
2454869.6306500002	167698.6406	177203.4219	432926.5938	494.24029541	496.35916138	648.49475098
2454869.6313100001	168398.6250	176506.0312	432481.3125	499.14569092	505.37582397	652.41949463
2454869.6320500001	167030.7500	176421.0781	433512.1250	497.50784302	505.59774780	657.91857910
2454869.6327100000	167193.2344	174413.4688	432749.1562	495.43621826	493.50860596	653.07006836
2454869.6419400000	164657.7344	174646.6094	429446.3125	490.38238525	501.53948975	652.17553711
2454869.6425999999	165847.8594	175035.8438	429687.0625	490.94110107	504.32901001	657.22088623
2454869.6433100002	164907.1406	172954.0469	426698.6562	493.48245239	497.30508423	649.76470947
2454869.6439800002	165529.4062	174329.3906	428501.3750	499.57440186	499.49829102	650.13989258
2454869.6446500001	164106.2812	173479.5469	427015.1562	502.55480957	499.03656006	651.53289795
2454869.6453100001	165697.0000	174031.7344	428333.6875	501.58880615	504.83898926	656.98791504
2454869.6459700000	164942.4688	173810.1719	428187.2188	490.36804199	502.88674927	657.88446045
2454869.6466299999	166700.0312	174506.5312	429906.2188	491.93157959	499.89834595	659.58874512
2454869.6472900002	166245.9688	174675.8281	428599.5938	496.03302002	508.70669556	651.57617188
2454869.6479500001	165109.9219	174382.7188	428219.1250	495.57998657	501.42453003	648.74322510
2454869.6486100000	164432.7188	174197.0938	427848.0625	497.53906250	497.44619751	651.72534180
2454869.6492599999	165328.7188	174125.9219	428756.8750	495.76168823	498.13259888	648.72271729
2454869.6499299998	161554.1250	170786.4062	420702.1562	494.52572632	494.97088623	650.10736084
2454869.6505900002	161666.3281	169645.6562	415567.3750	493.91146851	506.43823242	644.71893311
2454869.6512500001	161325.8281	172013.6875	419510.0938	488.18447876	504.76669312	652.92065430
2454869.6519200001	163374.2812	171567.3125	422540.8438	494.51531982	503.42474365	650.65454102

2454869.6525800000	164335.5781	171954.6875	423845.2812	494.67044067	499.24383545	648.60034180
2454869.6532399999	163300.3594	171707.1875	423786.0000	488.07019043	502.17984009	653.56799316
2454869.6538999998	163568.7188	172603.8594	425232.9062	490.49594116	500.16900635	648.11120605
2454869.6545600002	163439.2031	172350.6875	424893.6250	494.70156860	500.09527588	648.14520264
2454869.6552200001	162394.8750	172015.2969	420643.0000	489.72479248	501.22802734	646.51391602
2454869.6558800000	162773.2812	171338.0156	421697.3438	490.67788696	508.08413696	650.50885010
2454869.6565399999	163167.1719	171142.6562	422226.0625	497.45440674	501.29254150	645.88336182
2454869.6571900002	161758.8438	171356.7969	420660.5312	498.90347290	499.52029419	647.87170410
2454869.6578500001	162219.9531	171317.7656	422001.8438	493.70581055	496.42886353	648.48260498
2454869.6585100000	162470.7812	171316.1406	421006.6562	498.00552368	503.71173096	654.51672363
2454869.6591800000	163259.9062	172609.9688	424383.4688	498.20739746	502.59683228	651.91162109
2454869.6598399999	163837.0469	172678.2812	422969.1875	495.50885010	496.43286133	650.49633789
2454869.6605000002	160742.8594	169094.2500	415396.5938	498.69198608	501.67880249	644.50292969
2454869.6611600001	161734.0938	169970.9844	419375.4688	496.97015381	499.25714111	652.68939209
2454869.6618200000	162038.9688	171757.2500	420918.6250	492.06756592	497.53979492	650.90356445
2454869.6624799999	162894.6719	170227.1094	420102.3750	498.72702026	504.29559326	648.23834229
2454869.6631399998	161522.8125	170340.0781	417109.8438	496.35427856	499.60003662	649.01879883
2454869.6638000002	160394.2188	168942.2656	414624.0938	494.75085449	493.58901978	646.72741699
2454869.6644400000	159808.8594	168858.8906	413564.0938	500.56710815	498.02493286	649.50720215
2454869.6650999999	159268.6562	168393.8906	412029.6562	493.40078735	501.90774536	651.06146240
2454869.6657599998	158710.2500	168172.0000	414062.3750	493.92968750	497.81915283	649.14129639
2454869.6664399998	158186.1406	167992.2656	409235.8125	494.26480103	504.24340820	648.24426270
2454869.6670900001	157844.4219	165740.6406	408870.0000	502.48034668	503.07104492	648.00219727
2454869.6677500000	157211.7656	166033.2969	408979.4688	494.94970703	501.94433594	644.36743164
2454869.6684099999	157519.2344	165814.4688	405870.9062	490.75286865	504.14865112	642.96118164
2454869.6690900000	154247.5000	162986.5156	400356.0312	493.45156860	500.48611450	644.43243408
2454869.6697600000	152874.7188	162065.1562	396391.1562	495.37548828	504.52142334	650.41656494
2454869.6704199999	152264.4219	161933.7656	398331.0000	496.99716187	510.42092896	647.43463135
2454869.6710899998	148391.7500	156428.5000	383003.1562	500.25479126	499.74417114	640.64691162
2454869.6717599998	147617.7031	156482.0938	383601.4688	506.39083862	498.77563477	640.33471680
2454869.6724299998	147208.0938	156585.4844	382057.3750	492.48309326	510.17666626	641.99267578
2454869.6730900002	148149.3750	156687.6875	384003.0625	508.56814575	509.10546875	641.13250732
2454869.6737500001	145957.9219	155146.7188	382206.0312	490.91137695	506.54666138	647.52502441
2454869.6744100000	146873.1562	155053.8750	382763.0625	495.01095581	502.92153931	634.31256104

2454869.6750699999	144495.8438	152253.6562	375873.0625	510.59780884	503.31613159	638.13867188
2454869.6757299998	144609.0938	154242.3125	379505.0000	498.03057861	501.58105469	639.64324951
2454869.6764000002	146318.4531	154624.5000	380172.7812	501.77703857	506.57650757	641.63519287
2454869.6777200000	142874.7500	152249.7969	373209.5938	495.69100952	514.02014160	636.18969727
2454869.6783900000	140336.8281	149262.9688	365258.0000	496.34204102	504.95925903	633.41369629
2454869.6790600000	138339.6250	147960.8750	362209.1875	500.99029541	510.85485840	635.59875488
2454869.6797300000	138870.5781	147700.6406	361981.3125	495.89572144	500.42440796	637.06835938
2454869.6803899999	140871.7500	150644.0156	369818.6875	503.00213623	511.21429443	633.68206787
2454869.6810599999	142956.2031	151470.9219	372144.2812	498.39868164	499.68530273	640.48077393
2454869.6817399999	141080.2969	150072.5938	368432.5625	494.62878418	502.40228271	635.97271729
2454869.6823999998	140877.1875	150198.6875	369403.2500	504.68908691	511.15365601	641.01660156
2454869.6830600002	139980.4531	149879.7812	367029.0312	500.02133179	500.31250000	634.20013428
2454869.6837200001	138535.9062	147115.8906	362465.5312	499.72665405	508.91799927	634.30969238
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2454869.6850299998	133955.5938	142259.6094	350653.1875	504.66241455	512.63427734	629.68414307
2454869.6856900002	129241.8906	136743.1250	336567.5625	500.55487061	510.93826294	632.17553711
2454869.6863500001	125963.1250	135328.0625	333381.5625	501.48419189	509.98782349	631.19561768
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2454869.6889900002	124625.2578	132994.7188	324781.0000	504.77383423	508.03564453	619.27246094
2454869.6896600001	129106.7422	137235.7656	336674.1875	504.59448242	503.28457642	624.13940430
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2454869.6916299998	122884.6641	131682.2188	324881.9375	497.08309937	501.22839355	626.33898926
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2454869.6929500001	124013.1484	134092.0625	328117.0312	497.42514038	512.38928223	631.71557617
2454869.6935999999	121771.5078	128949.4141	317247.1250	502.88049316	504.55822754	624.18194580
2454869.6942699999	125491.3359	133919.9531	330535.5938	508.33023071	512.89520264	627.20532227
2454869.6949200002	129600.3359	138260.0625	339043.0625	501.33047485	503.58801270	634.55456543
2454869.6955900001	128938.1562	138465.0000	337630.3750	502.71041870	503.53225708	627.43914795
2454869.6962400000	129636.0703	137779.4219	338016.9062	507.40277100	511.66052246	627.86987305
2454869.6968999999	130622.2656	139242.5469	341355.9062	497.13284302	502.87963867	628.38537598
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2454869.6982200001	130004.6875	140068.0625	343704.9688	500.32781982	503.18960571	625.42614746
2454869.6988900001	130277.0000	139281.5625	340799.0000	500.57937622	512.94085693	632.72436523
2454869.6995500000	128956.5312	136776.1094	336917.3438	497.67630005	514.15753174	623.43212891
2454869.7002099999	122109.3047	130955.2266	320906.0938	500.99124146	509.19692993	625.78192139
2454869.7008600002	122286.6094	130821.7734	322379.3750	500.81060791	504.78884888	630.01873779
2454869.7015300002	129437.1641	138707.8125	339858.3438	502.03463745	508.10595703	627.50598145
2454869.7021900001	128958.8672	137175.0469	335102.8438	499.09585571	506.81628418	625.77471924
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2454869.7035099999	123310.1641	131615.9375	323737.5000	496.24166870	499.18136597	622.34039307
2454869.7041600002	114940.4531	124219.7578	306633.1250	500.85897827	515.75714111	620.67382812
2454869.7048100000	113255.9922	122407.4062	300806.7188	505.08901978	515.24096680	618.33160400
2454869.7054900001	116753.6484	124896.4688	306106.2188	502.56454468	506.93457031	622.38354492
2454869.7061299998	112031.5391	119793.1719	295233.2500	505.32702637	514.29876709	616.94842529
2454869.7068099999	104396.8125	111456.9453	274011.9688	500.25640869	514.38378906	615.78900146
2454869.7074699998	104422.8203	112631.0078	276122.2500	505.07083130	506.46719360	609.17669678
2454869.7081200001	112072.6328	119979.6406	292652.5938	502.04531860	507.13259888	617.80065918
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2454869.7094399999	106218.8438	113393.7891	278914.0312	511.70874023	510.14489746	609.44586182
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2454869.7114200001	95662.0000	102379.7656	249385.6719	500.24853516	504.59796143	596.01452637
2454869.7120800000	91267.0234	98899.7969	240491.7812	495.95959473	494.48468018	594.97045898
2454869.7127499999	88125.1875	93552.4766	228995.7500	491.36059570	492.72286987	579.89514160